U.S. Department
of Transportation
**Federal Highway
Administration**

# Analysis of PMS Data for Engineering Applications

## INSTRUCTOR'S GUIDE

NHI Course No. 131105

PREPARED BY:

TRDI

2602 Dellana Lane
Austin, Texas 78746
Office 512/327-4200
Fax 512/328-7246
www.trdi.com

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NATIONAL HIGHWAY INSTITUTE
Training Solutions for Transportation Excellence

*National Highway Institute*

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# NOTES TO INSTRUCTORS

## Pre-Course Activities

Before class starts, ensure that the classroom is arranged so that the view of the screen is unobstructed and that the participants have plenty of room to spread their notebooks and be able to take notes. Ensure that all audio visual equipment is set up and working properly and that you have plenty of supplies including flip chart, paper and markers. Instructors should familiarize themselves with the location of the lights and the lighting combinations that provide for the best viewing of the slides. Instructors should also familiarize themselves with the bathroom facilities and break rooms etc. in the building where teaching the course. Distribute course materials, sign in sheets and CEU forms before the start of the course.

## Opening, Welcoming, Housekeeping Duties and Remarks

Verify that each participant has received copies of all course material, such as the Participant Workbook and Reference Manual. Discuss the materials and how they will be used in the class. Explain any special segments i.e. guest speakers, field trip or special arrangements. Instruct participants to fill out sign in sheets at the start of the course.

Instructors should establish class starting times, lunch periods, breaks and ending times, etc. Discuss classroom facilities, location of restrooms, policy on smoking, food arrangements, provisions for messages and telephones, parking, and any other special conditions. The instructor should also point out the exit locations.

## Introductions

A senior manager from the host agency may wish to introduce the class. This helps acknowledge support for the course and material by upper management. The instructors should introduce themselves by giving a brief statement of their qualifications, educational background, professional experience relevant to the subject matter of the training course, and any other information which would establish their credibility with the participants.

## CEU Credits

The instructor should have a CEU form available at the beginning of the course and will give instructions on filling them out. The instructor should collect these forms by the end of the course.

## Course Evaluations

At the beginning of the last day, the instructor should pass out the Course Evaluation forms and instruct the participants to complete and fill the forms out throughout the day. This will ensure that the forms are not being filled out as they are rushing to leave at the end of the day.

## Certificates

A sign in sheet should be passed out at the beginning of the course. At the end of the first day, instructors should provide a copy of the course roster to the host agency so that they may begin preparing the certificates. Instructors will sign in and pass the certificates out at the end of the course.

## Final Responsibility

Instructors are responsible for sending the completed course roster, CEU forms and course evaluations to NHI. Instructors will receive copies of their course evaluations once they have been processed.

## Updates, Corrections & Omissions to the Course Material

TRDI has spent a great amount of time and effort to produce a well written and easy to follow course but it is inevitable that instructors and participants will find errors, omissions or text that will need updating. We encourage the instructors and participants to share these errors or concerns with the course material to TRDI so that corrections are made to subsequent versions.

## Tips on Facilitation for Instructors:

Each group of adults brings to class a variety of backgrounds and levels of experience. This diversity requires you to be responsive to the participants' different needs, goals for the class and learning styles.

**DO**

- Establish program schedules and norms
- Establish ground rules including punctuality, interruptions, number of breaks and other "housekeeping duties"
- Stimulate discussions by asking open ended questions:
    - "Who needs to be involved?"
    - "What experiences have you had with this?"
    - "Where are the barriers to making this happen?"
    - "When does this need to change in order for this to happen?"
    - "Why should you go with this program?"
    - "How can WE make this happen?"
    - "What questions do you have?" instead of "Do you have any questions?"
- Coordinate exercises and activities:
    - Clarify key points
    - Guide Problem solving
    - Reinforce ideas on flip charts
    - Emphasize application and utilization
    - Maintain and enhance self-esteem
- Reflect, expand and summarize participants' comments

**DON'T**

- Direct and control (unless needed)
    - *Do guide and lead*
- Evaluate and judge
    - *Do thank them for their participation and use rewards*
- Solve problems for others
    - *Do use their experience to lead participants to solutions*
- Allow the group to be irresponsible or get off track
    - *Do keep "war stories" short*
- Allow the discussions to become grip sessions
    - *Do lead them to solutions of those problems they can solve*

# TRAINING COURSE CHECK LIST

## Pre-course Activities

- ❑ Instructor’s computer set up and checked
- ❑ Ensure you have plenty of supplies including flip chart, paper and markers
- ❑ Audio visual equipment set up and checked
- ❑ Classroom seating arranged
- ❑ Distribute course materials, sign in sheets and CEU forms

## First Day Activities

- ❑ Brief Opening and Welcome
- ❑ Introductions of instructors and participants
- ❑ Collect issues and concerns related to the course from participants
- ❑ Discuss Housekeeping
- ❑ Discuss Course Schedule
- ❑ Discuss Break Policy

## Last Day Activities

- ❑ Distribute Course Evaluation forms
- ❑ Collect CEU forms
- ❑ Sign and distribute Certificates
- ❑ Collect recommendations for course changes
- ❑ Pack up audio visual equipment to ship back

# MODULE 1

# Overview of Engineering Applications of PMS

# Module 1
# Overview of Engineering Applications of PMS
# Instructional Time: 60 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

1. Identify issues and concerns amongst participants about subjects and concepts raised during the overview.
2. Summarize these on a flip-over chart and hang this at a visible location where they can be referred to during the balance of the course.

**Slide 1**

Module 1
Overview of Course
"Analysis of PMS Data for Engineering Applications"

Federal Highway Administration
Prepared By TRDI
(Texas Research & Development Inc.)

11/19/2002 Module 1 1

The first part of this course, reviews structure and principles of PMS and how they relate to engineering applications. The heart of the course presents example of actual engineering applications found in state highway agencies, such as PennDOT, WSDOT, WisDOT, ADOT, TxDOT, MDT and KDOT. Each day, a workshop is held for the purpose of stimulating participants to think about what they can do with their PMS to solve engineering problems.

**Slide 2**

Course Instructors

- Instructor 1
- Instructor 2
- Instructor 3

11/19/2002 Module 1 2

In this slide, the instructor should list their names and the agency for which they work for and then introduce themselves giving a two sentence summary of their qualifications. This slide would have to be prepared by the individual instructors teaching the course at any particular time.

**Slide 3**

Course Objectives

- Provide overview of PMS and related systems, techniques and databases
- Discuss results of engineering analysis carried out by several state DOTs, and demonstrate benefits of these studies
- Stimulate agencies to enhance their PMS data base and use PMS data in range of engineering applications

11/19/2002 Module 1 3

The objective of this course is to define the nature of engineering applications of pavement management data and to help the student recognize the value of engineering analysis to extend the benefits of their pavement management system. It is also our objective to report the results of engineering analysis which have been carried out by other state DOTs and to demonstrate the benefits that these previous studies have contributed to their respective agencies. Participants will learn basic PMS activities in five state DOTs. As a result of attending this course, students should be able to recognize potential engineering applications in their own agency and should be able to define the types of data and the basic approach that could be taken for engineering analysis as it will benefit their own agency.

**Slide 4**

## Module 1 - Objectives

- Review Basic Concepts of Pavement Management Systems
- Outline Principles of Engineering Analysis
- Quantify Benefits of PMS

11/19/2002 Module 1 4

The objective of this module is to present the basic concepts of pavement management for the students and to reinforce their understanding of the broader pavement management principles. A further objective is to introduce the participants to the concepts of engineering analysis specifically since many of them may look at pavement management primarily as a network prioritization process. Finally, the third objective of this module is to define the benefits of pavement management quantitatively as they have been determined through an engineering application in Arizona DOT. At the end of this module, the students will be able to list the basic principles of engineering analysis and will be ready to learn rapidly from subsequent modules.

**Slide 5**

## How Does PMS Relate To Your Engineering Activities

- Pavement (overlay) design analysis
- Materials & construction methods
- Preventive maintenance
- Pavement preservation strategies
- Pavement maintenance management

11/19/2002 Module 1 5

This slide outlines topics which will be covered in the course showing how pavement management data may be applied to engineering problems. A number of these will be covered in day one and the remainder will be covered in day two.

**Slide 6**

## Course Modules

| Day 1 | Day 2 |
|---|---|
| 1. Overview | 7. Materials - Construction |
| 2. Database needs | 8. Preventive maintenance |
| 3. Superpave monitoring | 9. Preservation strategies |
| 4. Performance modeling | 10. Maintenance effects |
| 5a. Workshop 1 | 5b. Workshop 2 |
| 6. Design analysis | 11. Evaluation & Closing |

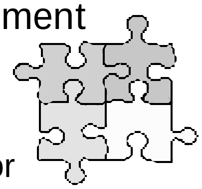
11/19/2002 Module 1 6

This slide outlines the modules covering examples of Engineering Analysis from 12 State DOTs. All analyses have been made possible by the availability of a PMS. After the basic overview and the discussion of database needs, three modules will be covered as listed above. A workshop about Superpave Performance Monitoring will be conducted to give the participants an opportunity to interact with each other.

On day two, four additional modules will be covered including a video of Preventive Maintenance techniques. A second workshop will be held in the afternoon, again to activate the participants and to stimulate their thinking and interaction. The course will close with an evaluation and a summary by the instructor.

**Slide 7**

## Pavement Management



Is a coordinated systematic process for carrying out all activities related to providing pavements

11/19/2002 Module 1 7

Pavement management is a coordinated systematic process that covers all those activities involved in providing and maintaining pavements at adequate level of service. These range from initial information acquisition to planning, programming, and execution of new construction, maintenance, and rehabilitation, to details of individual project design and construction; to periodic monitoring of pavements in–service.
A pavement includes shoulders & all structural elements of the roadway (i.e., all layers). Also, load-carrying capacity of the subgrade is implicitly included.

**Slide 8**

## Pavement Management System

Rational procedures that provide optimum pavement strategies based on predicted pavement performance incorporating feedback regarding the various attributes, criteria, and constraints involved.

11/19/2002 Module 1 8

A PMS provides decision-makers at all management levels with optimum strategies derived through clearly established rational procedures, and evaluates alternative strategies over a specified analysis period on basis of predicted values of quantifiable pavement performance, subject to predetermined criteria and constraints.
It involves an integrated, coordinated treatment of all areas of pavement management, and is a dynamic process that incorporates feedback regarding various attributes, criteria, and constraints involved in an optimization procedure.

**Slide 9**

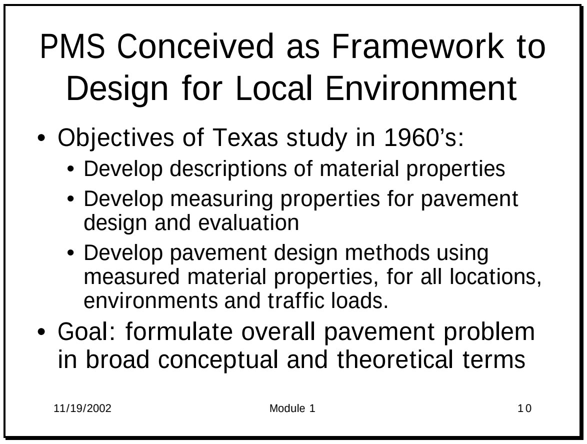
## Overview of PMS & Related Issues

- Network & project levels
- Database issues
- Performance & design model applications
- Pavement preservation and rehabilitation
- Pavement maintenance systems

11/19/2002 Module 1 9

In this course we will present an overview of pavement management and related issues. Five topics are outlined in this slide. The first three bullet points will be treated today, the last two bullet points will be treated in the second and final day of the course.

**Slide 10**

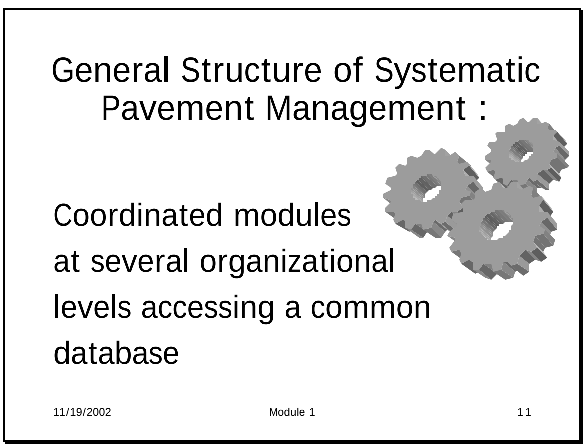



In 1967 an NCHRP project was one of the first efforts in applying systems engineering to pavement design. The Texas Highway Department recognized the need for a system for organizing and coordinating their pavement research program and updating their design system, and developed a working design model in connection with the Texas Transportation Institute. The purpose was to develop a basic framework to adapt to local environment information such as on AASHO Road Test, to be accomplished by carrying out the following specific objectives:

- develop descriptions of significant basic properties of materials used in roadway structures;
- develop procedures for measuring these properties in manner applicable to pavement design and evaluation;
- develop procedures for pavement design utilizing measured values of basic properties, which would be applicable to all locations, environments, and traffic loads.

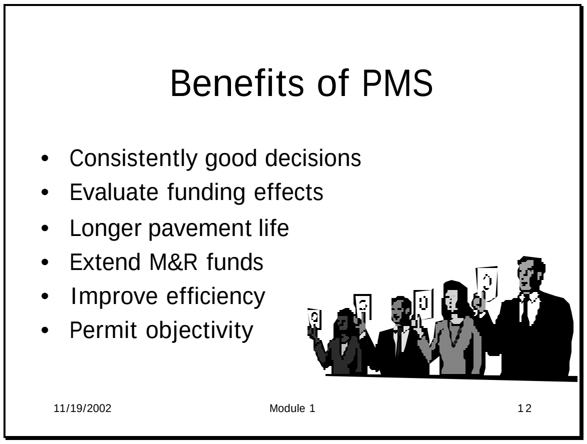
The goal was to "formulate overall pavement problem in broad conceptual and theoretical terms"; which would enable solution of a variety of pavement problems that have long plagued engineers.

**Slide 11**



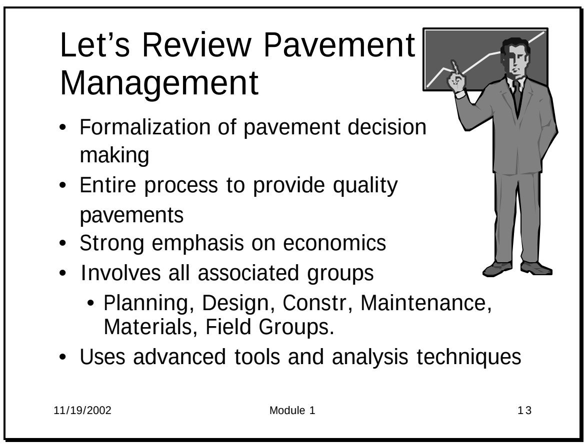

As a part of PMS development at the project level, the design process was structured and its components were identified more specifically in 1965-67.

**Slide 12**



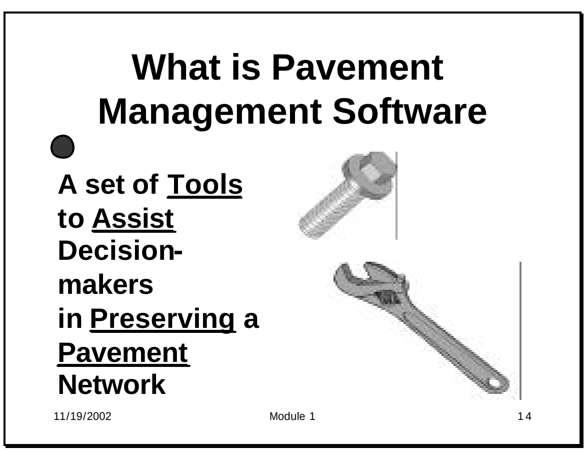

This slide outlines six major benefits of Pavement Management. A good pavement management system provides consistently good decisions, and enables the user to evaluate the effects of funding levels. It provides longer pavement life, extends the benefits and results of maintenance and rehabilitation funds. It also improves the efficiency of the organizations and permits objectivity in making pavement management and maintenance rehabilitation decisions.

**Slide 13**



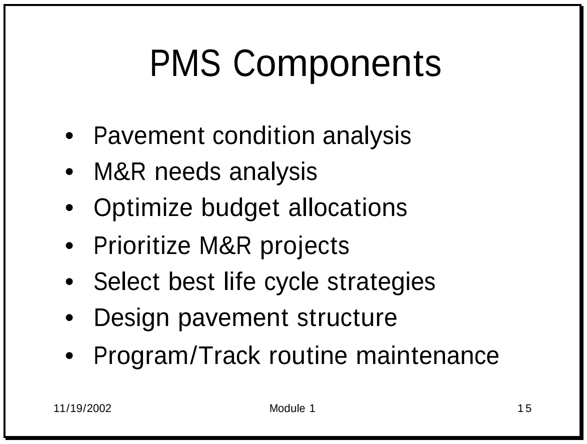

This slide describes what pavement Management, the "process", actually is. It is a formalization of decision making, which includes the entire process required to provide quality pavements. Pavement management uses advanced tools and analysis techniques to function smoothly. There's a strong emphasis on the use of life cycle cost economics. Finally, pavement management involves all associated groups within an agency ranging from planning, design, construction, maintenance, materials and field operating groups.

**Slide 14**




Pavement management software is a set of tools which can assist decision makers in making good decisions and in preserving their pavement management system or network. A pavement management system is not a computer program, but software is essential in operating a PMS.

**Slide 15**

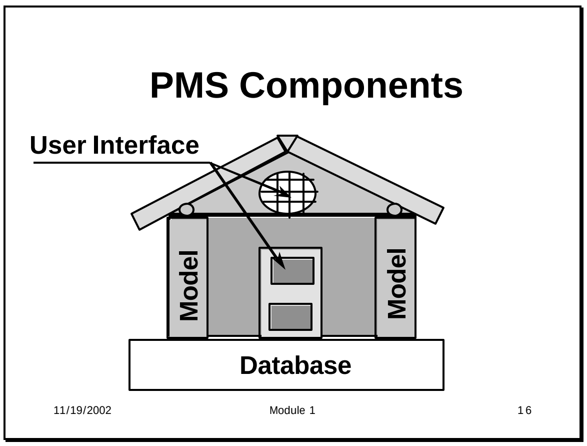



There are many ways to look at a Pavement Management System. In this particular preview, we define seven basic components or steps in the process. These include:

1. pavement condition analysis
2. maintenance and rehabilitation needs analysis,
3. optimization of budget allocations,
4. prioritizations of maintenance rehabilitation projects.

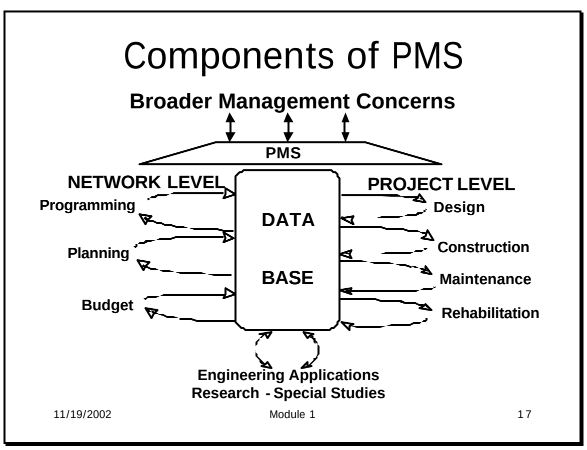
From these steps the best life cycle strategies for one or more projects are selected. The individual pavements or rehabilitations structures are designed and the PMS provides a program for tracking routine maintenance activities and obtaining follow up feedback information.

**Slide 16**



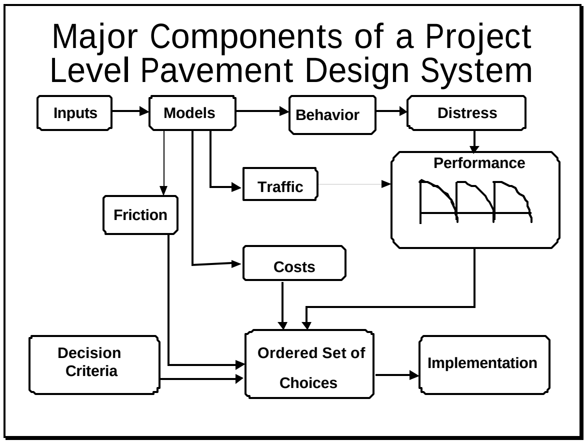

This conceptual house illustrates the inter-relations of PMS components. The foundation of the house and of the PMS itself is the database. The models hold up the structure itself and the doors and windows provide user interfaces or ways to get at the results of the PMS.

**Slide 17**



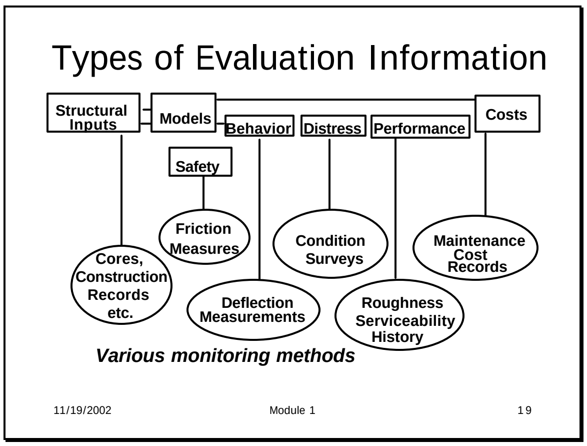

Pavement management must be capable of being used in whole or in part by various technical and administrative levels of management in making decisions regarding both individual projects and an entire highway network. All functions are essential, but not all functions need to be active at same time. In planning future construction consider individual project design in only an approximate way. A PMS can be viewed as a set of connected modules or "building blocks."

**Slide 18**




This slide was first developed in 1966 in a National Cooperative Highway Research Program Project to develop improved pavement design. It became clear at that point that it was necessary to model the pavement design process ranging from inputs through models to various outputs including response, distress and performance. These items combined with cost and traffic provide an ordered set of choices which can be selected in the face of decision criteria for implementation on a particular project.

**Slide 19**




This slide utilizes the structure of the pavement management system outlined in the previous slide. Just as a doctor can not tell everything about the health of a human being by measuring temperature or blood pressure alone, neither can you tell everything about a pavement by measuring only deflection or only distress. Each measurement tool has its own purpose for evaluating the pavement, as illustrated in this slide. Safety for example is evaluated by measuring surface friction while pavement distress is evaluated with condition of distress survey. Etc.

**Slide 20**

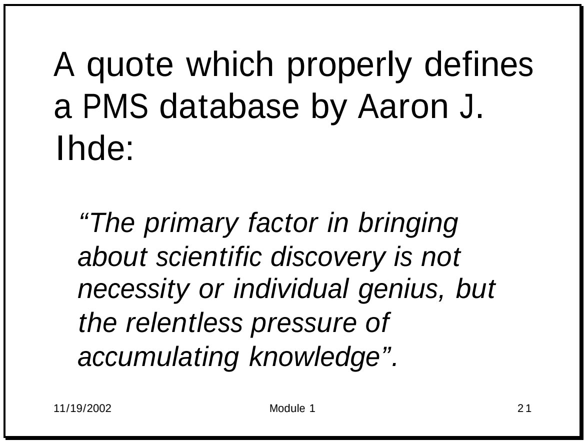
## Functions of Pavement Evaluation in PMS

- Check design predictions
- Schedule rehabilitation
- Improve design models
- Improve construction and maintenance
- Updating network programs

11/19/2002 Module 1 20

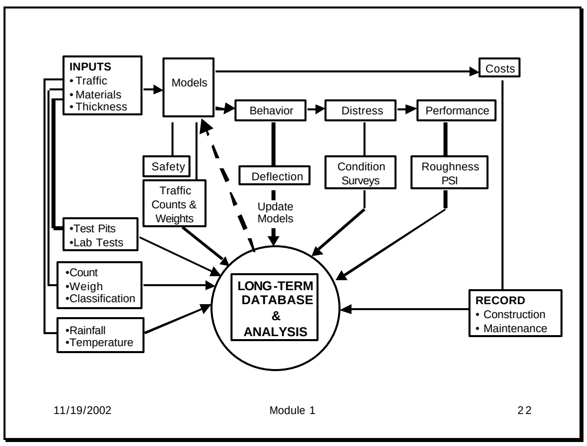
There are several functions of pavement evaluation as applied in pavement management. Five of the most important functions or uses of evaluation information are summarized in this slide.

**Slide 21**



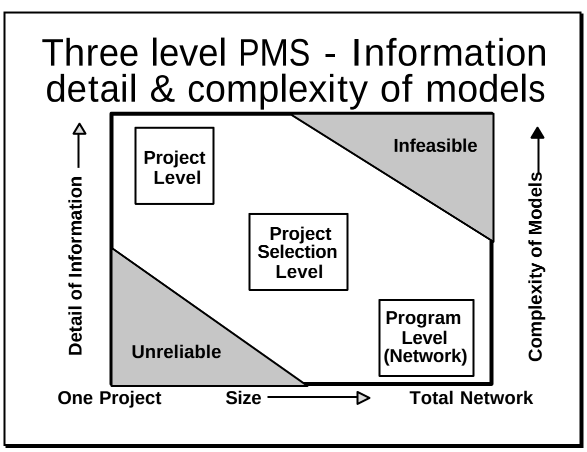

This quote gives a proper background for a pavement management database or any other database. It points out that accumulated knowledge is the most important aspect of new scientific discovery. Thus, the continuous maintenance of a good pavement management database will lead to improved scientific discovery about pavement performance. That's what databases are all about.

**Slide 22**




Please refer to the Reference Manual for a larger version of this slide. It is a continuation of a previous slide which shows the inter relationships of input models, behavior, distress, and performance tied to the type of data collected and stored in a pavement management database for each of the factors. It further shows that if this data is recorded over the longer term in the database and is properly analyzed, it can be used to modify, calibrate and update the models in the Pavement Management System. This is the purpose of pavement design and rehabilitation design. It was the original SHRP purpose of long-term pavement performance studies; when properly done it will ultimately lead us to improved pavement models.

**Slide 23**

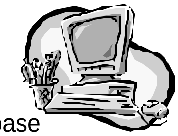



This slide is relatively complex but very important to your understanding. It relates the amount of information and detail of information needed to do Pavement Management at the project level vs. the network level and it also defines the complexity of the models related to these items. For example, if we look at the left vertical axis, "detail of information" we can see that a great deal of information is required for the project level and a smaller amount of information is needed for the program or network level. We've also introduced the project selection level in between, which most states use and more information is needed for selecting projects than is available for the network alone.

On the other hand, on the right vertical axis we look at complexity of models. It is infeasible to use very complex models for program or network level activities. It is more feasible to use relatively complex models such as life cycle cost analysis at the project selection level. At the project level, very complex design, rehabilitation and cost analysis models can be used.

**Slide 24**

## Technical User Issues



- Database design/operation
- Data acquisition methods
- Ensuring adequacy of database
- Predictive Models
- Performance Criteria
- Models for priority analysis and network optimization
- Verification of models

11/19/2002 Module 1 24

From a technical perspective, PMS involves a large number of issues and questions that must be appreciated if technical activities are to be meaningful.

**Slide 25**

## Essential Requirements of PMS

- Easily updated/modified as new information and models become available
- Considers alternative strategies
- Identifies optimum strategy
- Bases decisions on rational procedures with quantified attributes, criteria, constraints
- Uses feedback information regarding the consequences of decisions

11/19/2002 Module 1 25

Pavements are complex structures involving many variables, load, environment, performance, construction, maintenance, materials, and economics. In order to design, build, and maintain better pavements, the various technical and economic factors should be well understood. A very large investment has been made in pavements and billions more will be spent annually on maintenance and upgrading. Even marginal improvements in the component technologies of pavement management, and in the process itself, can result in large absolute savings.

**Slide 26**

## Summary of PMS

- Network and project level
- Several major subsystems
- Performance database for model development
- Proper information flows
- Pavement evaluation

11/19/2002 Module 1 26

PMS is a broadly based process for an entire set of activities required to provide and maintain pavements. Several important concepts are:

- In some agencies, network level incorporates project selection and program level.
- Planning, design, construction, and maintenance have different degrees of influence, with planning having a high initial influence and maintenance having a higher degree of influence as pavement ages.
- Database of historical pavement performance provides basis for developing wide variety of models, including those for pavement deterioration.
- Proper information flows also represent very important function in PM for both network and project levels, and between them.
- Pavement evaluation represents means for checking how well design, construction and maintenance objectives have been satisfied, for updating schedules, and for decision support.

**Slide 27**

## Purpose of PMS Engineering Analysis

The use of pavement management data to evaluate and improve structural designs, materials, mix designs, construction, preservation strategies, rehabilitation, and preventive maintenance of pavements.

11/19/2002 Module 1 27

This slide is self explanatory and the instructor can read from the slide and expand on the concepts in his own words. Basically, engineering analysis, is the use of the pavement management database, to make predictions and analysis of all kinds related to the pavement management process.

**Slide 28**

## Engineering Analysis Essential part of PMS

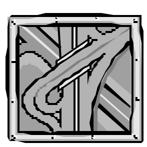
- Pavements are engineered structures, therefore engineering analysis:
  - Improves pavement performance
  - Can be used for network or individual problems
  - Is essential for feedback purposes
  - Affects future activities - design, construction maintenance, standards, and specifications
- Involves both project and network level data

11/19/2002 Module 1 28

Engineering analysis is an essential part of PMS and can assist agencies to improve performance of the state's pavement network and address difficult engineering related issues.
Mostly a PMS works at two separate areas, network and project level, a hard dividing line between the two is difficult to draw. For the most part, the same type of data is needed for both types of activities but more detail is beneficial for project analysis.

**Slide 29**

## Sources of Engineering Data other than from PMS database



- Research data files
- Construction records
- Material test records
- Additional field evaluations
- Project plans
- Additional structural evaluation and/or materials testing
- Expert opinion and forensics
- Maintenance Management Systems

11/19/2002 Module 1 29

Often the data needed for the use of the Pavement Management database is not computerized. The data may come from a number of different places within the organization. For example, most materials test records are in flat files in the laboratory. More and more Pavement Management systems are working to get all of their data in an electronic form for regular access and use. If data is to be analyzed on an engineering basis, it is essential that it be put into electronic format. Another major aspect of the engineering data is that it has a common referencing system. If data is accepted from a file folder in the materials branch, it is essential that the station number and the project location be clearly identified and that it be the same as the project location identified in the computer base.

**Slide 30**

## Engineering Application Examples from following State DOT's

- Arizona
- California
- Florida
- Georgia
- Kansas
- Maryland
- Michigan
- Montana
- Pennsylvania
- Texas
- Washington
- Wisconsin

11/19/2002 Module 1 30

A total of 18 examples will be covered during the course from the 12 states listed here.

**Slide 31**

## Arizona State DOT's Engineering Analysis Elements

- Module 1:
  - Overview of ADOT PMS
  - Methodology to show benefits of using a PMS
- Module 3:
  - Superpave performance monitoring
- Module 6:
  - Evaluating overlay design techniques
- Module 7:
  - Effectiveness of various overlays and surface treatments

11/19/2002 Module 1 31

The Arizona DOT has an outstanding Pavement Management System, which has been used for the last 22 years. Four examples of the results of using that Pavement Management System for Engineering Analysis are presented. These are outlined in the slide and are covered in Modules 1, 3, 6 & 7. Prior to covering the methodology to show the benefits of using the Pavement Management System an overview of the ADOT PMS is presented.

**Slide 32**

## ADOT's PMS Overview

- Pavement network 7600 center line miles
- Condition data collected annually at each milepoint
- Centralized Pavement Management Organization with 11 staff
- Budgets increased from $35 million in '80 to over $100 million now

11/19/2002 Module 1 32

Pavement Management Branch is part of Materials Group, this Group reports to Highway Operations Engineer, who in turn reports to the State Engineer, who reports to the Director of DOT (4 management layers). PMS responsibilities are highly centralized.
Concrete Roads are not part of PMS (different branch), but test data on concrete are recorded in PMS. Initially, PMS only used at Network Level to assess overall budget needs (Network Optimization System). ADOT is in a transitional phase to a new PMS system with more emphasis on Project Levels.

**Slide 33**



- Demonstrate benefits of PMS to both Administration and Legislature, and do it in quantifiable terms.
- Assess importance of well maintained, accessible and comprehensive PMS database.
- Demonstrate usefulness of pavement modeling techniques.

**Slide 34**



Two data files were obtained from ADOT:

1. PMS dbf (database file), including distress survey info, up-to-date to end of 1997.
2. Projmod.dbf, including construction details, up-to-date to end of 1995.

TRDI created a master file combining the two ADOT files, but only for the following two time periods:

1. 1981-1982-1983 (Pre-PMS)
2. 1993-1994-1995 (Full PMS)

All performance indicators were evaluated, but Roughness gave the most robust data. Visual Modeler runs were carried out for many combinations of road classes, road structure categories, regional factors, traffic categories. For this study, the best statistical results were obtained by grouping together all categories, thus maximizing the number of records.

**Slide 35**



Six different sets of analysis were run, one for each of the categories of pavements outlined in this slide.

**Slide 36**

## Five Performance Indicators

1. Roughness
2. Cracking
3. Patching
4. Friction
5. Flushing

11/19/2002 Module 1 36

Five performance indicators were selected for the analysis, roughness, cracking, patching, friction and flushing. All of this data was available in the pavement management database.

**Slide 37**

## Results

- Roughness by far the best indicator of performance and shows the best correlation for data set.
- Cracking shows stable relationships, but not as robust as for roughness

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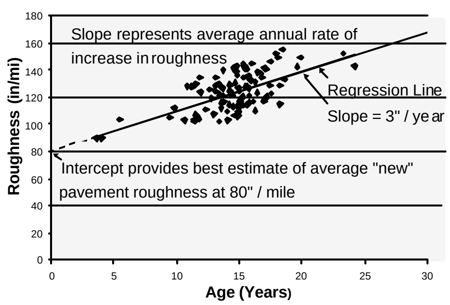
Of all of the performance indicators that were tested, roughness is by far the best indicator of performance and shows the best correlation for the data set. Cracking shows stable relationships but the results were not as robust as for roughness. Thus, roughness was selected for the continuing analyses.

**Slide 38**

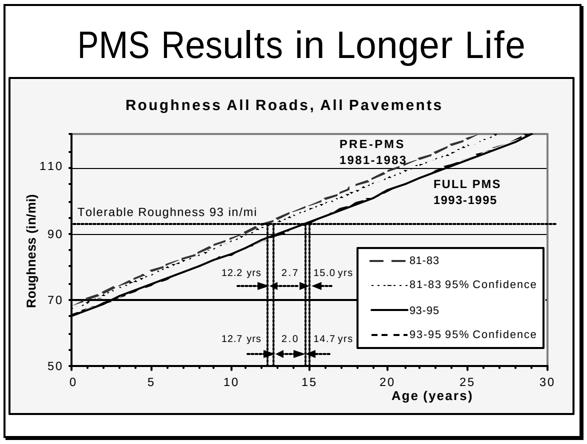
## Quantify With Visual Modeler




11/19/2002 Module 1 38

Slide modeler is an analysis package which was developed for the FHWA and the state of Pennsylvania DOT. It provides a good tool for using pavement management data for building models such as that shown. This is an example of the kinds of analysis which was run and does not depict real data. A plot is made of roughness vs. age for each pavement in the data set, about 7 thousand sections for each of the three years, e.g. 81-83. This provides approximately 21 thousand data points. A regression line is then fitted to the data and the intercept on the Y axis represents the best estimate of average “new pavement roughness”. In this case, 80 inches per mile. The slope of the line co-efficient “b” represents the average annual rate of increase in roughness, in this case 3 inches per year. Since the database is made up of sections with various ages, a wide range of age vs. roughness is included and a full spectrum of age can be covered.
It is important to note that this analysis does not depict the rate of roughness increase for any individual section but for the data set as a whole.

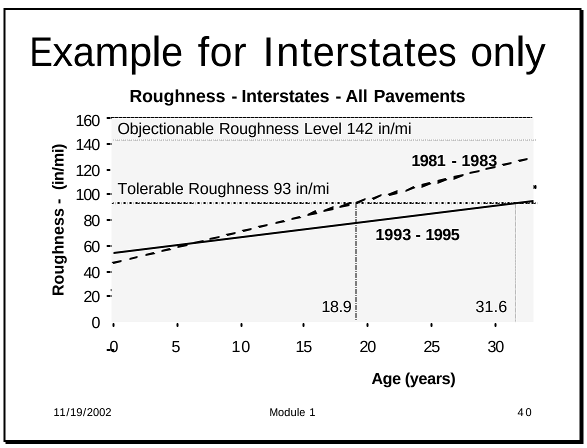
**Slide 39**




The type of analysis illustrated on the previous slide was run on two data sets. All the data points in 81-83 represent the pre -PMS condition. Obviously, it was not possible to run data prior to 1980 because the Pavement Management System did not exist and thus no data was available. On the other hand, it was felt that the effect of the Pavement Management System in the first three years of its operation would have had little impact on the individual roughness data. For the full impact of Pavement Management data points from 1993, 94 & 95 were taken and a similar analysis was run.

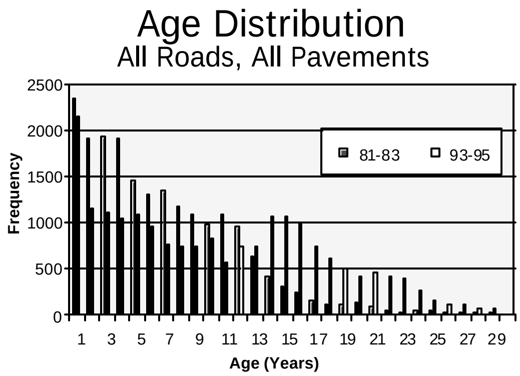
The ADOT establishes tolerable roughness levels of 93 inches per mile. These analysis shows that prior to PMS all pavements on the average were reaching this tolerable roughness level after 12.2 years. Under the full operation of PMS in 1993-1995, pavements were reaching these levels after 14.9 years, a gain of 2.7 years or 22 percent life. More conservatively the 95 percent confidence levels were run on both the analysis. The external confidence bounds are not important but the confidence limits between the two data points range from 12.7 to 14.7 years. Thus, 97 percent of the time the gain in pavement life was 2 years or 14 percent.

**Slide 40**




When the similar analysis was run for interstate pavements only the analysis was more dramatic. Pavements prior to PMS were reaching the maximum tolerable roughness level after 18.9 years during the1993-1995 data set the projected life is 31.6 years, a gain of 12.7 years or an amazing 67 percent. It should be pointed out that we do not intend to claim that this analysis proves that pavements in general are lasting 67 percent longer under the operation of a Pavement Management operation system. However, in many cases in Arizona they did.

**Slide 41**




During Pre-PMS, many roads were younger than 13 years old; in the Full-PMS period pavements are more uniformly distributed over some 23 years age range. This indicates that roads are lasting longer under good PMS practices. The instructor should tell the participants that the complete details of the final analysis are included in the Reference Manual.

**Slide 42**

ADOT's Budgets 1981-1996 (millions)

| Fiscal Year | Preservation | | New Re-construction | | Pavements Total | |
|---|---|---|---|---|---|---|
| | $$ | Miles | $$ | Miles | $$ | Miles |
| 1981 | 43 | 400 | 115 | 43 | 158 | 443 |
| 1982 | 28 | 278 | 133 | 45 | 161 | 423 |
| 1983 | 39 | 386 | 93 | 20 | 132 | 406 |
| 1984 | 56 | 544 | 183 | 25 | 239 | 569 |
| 1985 | 48 | 280 | 92 | 27 | 140 | 307 |
| 1986 | 48 | 290 | 145 | 24 | 193 | 314 |
| 1987 | 47 | 275 | 141 | 52 | 188 | 327 |
| 1988 | 67 | 296 | 150 | 90 | 217 | 386 |
| 1989 | 56 | 269 | 205 | 67 | 261 | 336 |
| 1990 | 78 | 371 | 221 | 92 | 299 | 463 |
| 1991 | 70 | 250 | 181 | 71 | 251 | 321 |
| 1992 | 88 | 308 | 74 | 35 | 162 | 343 |
| 1993 | 77 | 275 | 56 | 17 | 133 | 292 |
| 1994 | 60 | 209 | 69 | 22 | 129 | 231 |
| 1995 | 62 | 251 | 120 | 40 | 182 | 291 |
| 1996 | 68 | 222 | 222 | 53 | 290 | 275 |
| **TOTAL** | **935** | **4,904** | **2,200** | **723** | **3,135** | **5,727** |

This slide shows the ADOT pavement budgets for preservation and new or reconstruction along with projected savings based on the early analysis of 22.9 percent or 14.7 percent. You can see that the savings approximate half a billion dollars total over the time frame.

**Slide 43**

## Quantification of Benefits

- Improved Pavements with longer life:
- Total Budget for yrs 81-96: $3,135 million
- Average increase in life 2.0 yrs or 13.5%
- Minimum increase in life 1.3 yrs or 8.6%
- Average corresponding benefit over 16 years of $423 with minimum of $270 million at 95% confidence.

11/19/2002 Module 1 43

The total budget for preservation and new and rehabilitation efforts combined totaled $2.8 billion over the period 81-95. If we take the revised average increase in life of two years or 13.5 percent and a minimum increase in life of 1.3 years or 8.6 percent. The average corresponding benefits over 16 years were 423 million dollars with an absolute minimum of 270 million dollars with 95 percent confidence. These are extremely large savings. However, Pavement Management is not free. It does cost money to operate a good Pavement Management System; therefore, it is important to look at the cost of the Pavement Management System itself and then the benefit analysis of operating a PMS.

**Slide 44**

## ADOT PMS Development Costs

Consulting Services 1979 $300K
Temporary Staff 1979 – 1983 $400K

Total $700K

Average for 16 years = $43,700

Amortized 25 years @4% = $50,000

11/19/2002 Module 1 44

ADOT expended about $300 thousand dollars on consulting services to develop a pavement management staff. They estimate that during the period of 1979 to 1983, they spent an additional $400 thousand on temporary staff, totaling $700 thousand in development. The average cost spread over the 16 years of the study would be $43, 700 per year. Alternatively, the cost could be amortized over an estimated 25 years of life for the Pavement Management System before major renovations might be required. This would produce an average cost of $50 thousand per year.

**Slide 45**

## ADOT PMS Operating Costs Example

| | 1981 | 1996 |
|---|---|---|
| Labor | $275K | $370K |
| Travel | $30K | $30K |
| Annual capital cost for equipment | $65K | $65K |
| Equipment Operat. | $60K | $65K |
| Annual Total | $430K | $525K |

11/19/2002 Module 1 45

This slide shows the cost that ADOT has recorded for operating its Pavement Management System labor, travel, annual capital cost for equipment and equipment operation. These totaled $430 thousand in 1981 rising to $525 thousand in 1996.

In the next slide we show how this combines with cost of developing the system to produce total cost.

**Slide 46**

## ADOT Total PMS Costs

| | **1981** | **1996** |
|---|---|---|
| DEVELOPMENT | 44,000 | 44,000 |
| OPERATING | 430,000 | 525,000 |
| TOTAL | 474,000 | 569,000 |

TOTAL FOR 16 YEARS = $8,340,000

11/19/2002 Module 1 46

If we add the development cost averaged over the 16 years of $44 thousand we get a total PMS cost of $474 thousand in 1981 and $569 thousand in 1996. The cost in intermediate years range between these two levels so that the total cost for the 16 years was $8,340,000.

**Slide 47**

## ADOT's PMS Total Benefits/Costs

Total PMS costs $8.3 Million over 16 yrs. Benefits at minimum confidence level $270 Million, at average level $423 Million.

Minimum at 8.6% increase in life:

$$\text{Benefit/Cost Ratio} = \frac{\$270\ \text{Million}}{\$8.3\ \text{Million}} = 33 \text{ to } 1$$

Average at 13.5% increase in life

$$\text{Benefit/Cost Ratio} = \frac{\$423\ \text{Million}}{\$8.3\ \text{Million}} = 51 \text{ to } 1$$



As previously determined the cost of operating the Pavement Management System in Arizona totaled $8.3 million over 16 years. The average benefits previously calculated at minimum confidence intervals was $270 million and at the average level $423 million. The $270 million was for an 8.6 percent increase in life and produced a benefit/cost ratio absolutely minimum of 33 to 1. The average increase in life of 13.5 percent produces a realistic benefit cost ratio of 51 to 1 as shown above.

**Slide 48**

## Total Benefits/Costs Sensitivity Including User Costs

- Assume minimum benefits (95%) of $270 million with 33:1 benefit cost ratio (BCR)
- World Bank: User benefits are 4 - 10 x cost of road expenditures,
- Benefits to Arizona citizens over 16 yrs would be at least $ 1 billion, with BCR of more than 100:1



Total benefits to the citizens of Arizona are not only the savings in pavement construction and maintenance costs but more importantly are the savings in user costs plus agency costs. According to the World Bank, user benefits range from 4 to 10 times the costs of the road expenditures themselves taking a conservative value for the citizens of the state of Arizona over the 16 year period 1981 -1996 realized equals 4 times $270 million or over $1 billion in savings with a total benefit cost ratio of over 100 to 1. That is 100 dollars for every 1 dollar invested in the Pavement Management System.

**Slide 49**

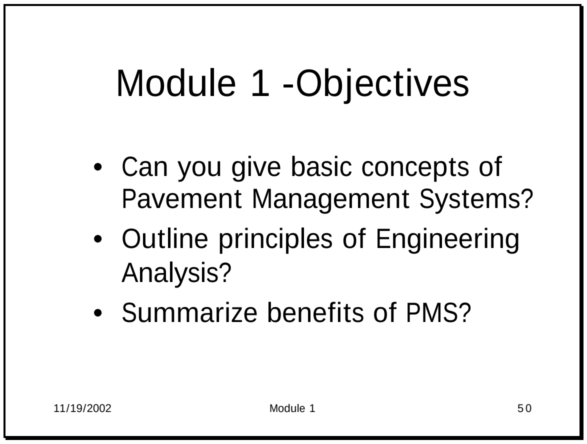
## Summary of PMS Benefits

- Many "general" benefits, such as improved communications, better decision taking, asset management, etc are present in PMS but difficult to quantify.
- With well maintained comprehensive database, benefits can indeed be defined in number of ways, and reliably quantified.
- As shown in Arizona, they are sizeable.



We felt it would be desirable before undertaking this detailed discussion of engineering analysis of Pavement Management data to show you these results of benefit analysis for the use of Pavement Management.
This slide illustrates that the benefits are sizable ranging up to 100 dollar benefit for every dollar spent on a Pavement Management System. The results of engineering analysis exceed even those pointed out here and will be covered in great detail during the next two days.

**Slide 50**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. Identify issues and concerns amongst participants about subjects and concepts raised during the overview.
2. Summarize these on a flip chart and hang this at a visible location where they can be referred to during the balance of the course.

# MODULE 2

# Database Needs & Elements

# Module 2
# Database Needs & Elements
# Instructional Time: 35 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

3. What is your involvement with a database (central or in your own group)?
4. Are you providing data or using them?
5. Do you have easy access to data that are important for your job?
6. What are the major concerns about databases in your agency?

**Slide 1**

Module 2
Database Needs and Elements for Engineering Applications

11/15/2002 Module 2 1

An important aspect of pavement management is the database. If you are going to analyze engineering data or make engineering applications of pavement management data, you must have the data available. In this module we will discuss the need for a database and elements in that database as they relate to engineering applications.

**Slide 2**

Module 2 - Objectives

- Identify data needs for Engineering Applications
- Identify importance of electronic databases
- Clarify data organization needs

11/15/2002 Module 2 2

The objective of Module 2 is to identify for the students the data that is necessary for any good pavement management system and particularly for its application in engineering analysis. It will present to them the importance of electronic databases and will indicate how they can modify the organization of their own data for subsequent and more practical engineering analysis.

**Slide 3**

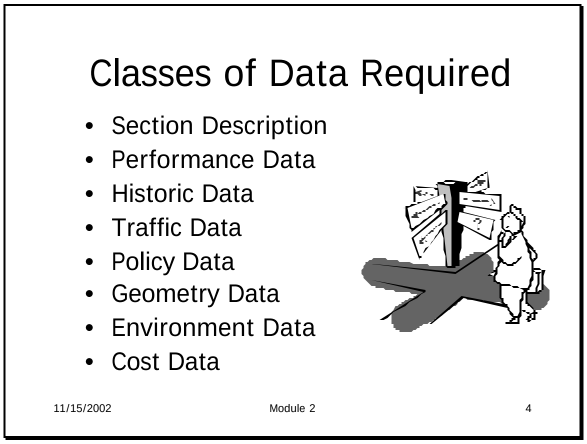
Scope for Database Needs & Elements

- Network & Project Level quality data
- Additional data for engineering analysis
- Data mining
- Data accuracy, reliability, & applicability
- Integration and centralization of data
- Statistical Analyses

11/15/2002 Module 2 3

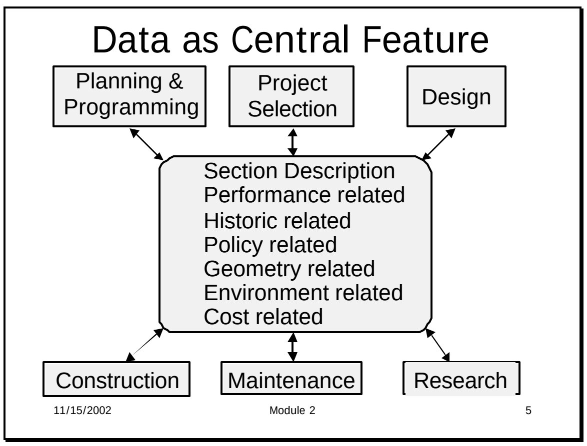
You have previously discussed pavement management at the network level and at the project level. Clearly, here is where the bulk of the data well come from for engineering analysis. The network data is not as complex as is the project level data but there is more of it. Many more pavement sections are involved in the network than in individual project details. Not all the data needed for engineering applications is included in the pavement management database directly and therefore, it will be necessary in some cases to get additional data for the analysis. Many of you have heard of data mining. This is generally the use of various kinds of data to obtain more information than was originally developed or originally intended. We will discuss data mining briefly. Data accuracy, reliability and applicability are important and will be discussed as will integration and centralization of the data. Finally, we will discuss several types of statistical analysis that can be used in engineering application analysis.

**Slide 4**



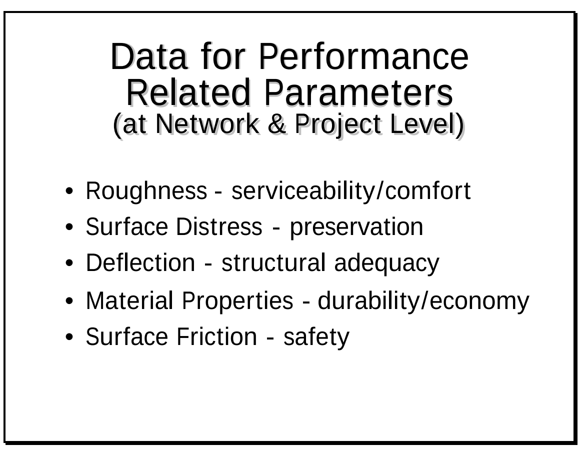

All activities required for providing pavement structures should be coordinated in a cost effective manner. Support of these activities requires a broad database involving every division within agency. While focus of PMS is often on condition and performance of surface and structure, a comprehensive PMS uses data from variety of sources. The instructor can read from this slide the various classes of data that are needed in addition to performance in section identification description.

**Slide 5**




This slide shows the various types of data as the central block in the slide and shows how Planning Project Selection Design Construction, and Maintenance and Research interact with the data, both using the data from the central database and inputting data into the central database. These two aspects are shown by the fact that two headed arrows are used to connect all the blocks.

**Slide 6**




As we saw in Module 1, performance is basically the serviceability history of the pavement on how well it performs its function. However, there are a number of other factors which are indicators of performance. This includes surface distress, deflection, changes in material properties and surface friction as a safety indicator. Each of these five categories of data can be used either as a performance measure or as an indicator of performance.

**Slide 7**

## Example of Use of Performance Related Data: <u>Roughness</u>

**Network Level**

a) Describe present status

b) Predict future status (deterioration curves of roughness vs. time or loads)

c) Basis for priority analysis and programming

**Project Level**

a) Quality assurance (as-built quality of new surface)

b) Create deterioration curves

c) Estimate overlay quantities

11/15/2002 Module 2 7

This slide outlines how roughness or present serviceability index (PSI) is used at both the network and the project level. The instructor can discuss the information from the slide. Performance data is primarily used at the network level for predicting future status and thus to develop time history budgets and programs. At the project level, roughness is primarily used as a quality control or quality assurance methods but also can be used to create individual deterioration curves for selection of project overlays and estimating overlay quantities.

**Slide 8**

## Example of Use of Performance Related Data: <u>Deflection</u>

**Network Level**

a) Describe present status
b) Predict future status
c) Identify structural inadequacies
d) Priority programming of rehabilitation
e) Determine seasonal load restrictions

**Project Level**

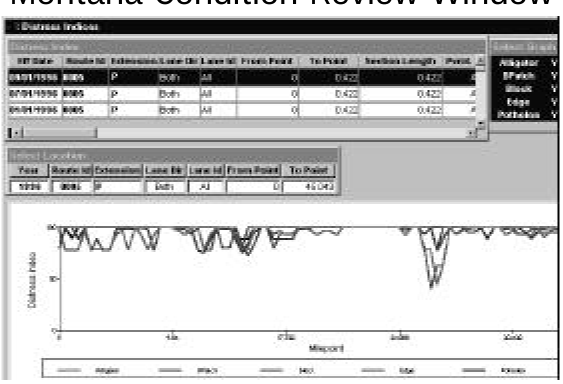
a) Input to overlay design
b) Determine structural adequacy
c) Estimate remaining service life
d) Estimate required load restrictions

11/15/2002 Module 2 8

Deflection can be used at both the network and the project level, however, it is used primarily as a project level indicator of performance because most pavement management systems do not have a complete set of deflection data at the network level. However, those that do can use it in the five ways outlined listed under network level, a through e above.
On the other hand, deflections are very often used at the project level to evaluate structural adequacy to calculate overlay thicknesses and designs, to estimate remaining service life and to estimate road restrictions.

**Slide 9**

## Montana Condition Review Window



This slide illustrates one state's plots of performance data. The data is most useful if it can be presented in such a way that it can easily be reviewed as demonstrated in this window. Example of Performance Related Use of Database by Montana DOT. Windows shows PI data for cracking, patching, edge deterioration and potholes in both graphical and tabular formats. The engineer can zoom in on any section in the network to view the condition data, and print a report of the data for any time period in the database.

**Slide 10**

## Data for Historic Related Parameters
(at Network & Project Levels)

- Maintenance - Effectiveness
- Construction - QA/QC, Acceptance testing, as-built records
- Traffic - growth, composition, controls
- Accidents - High risk sites, countermeasures

11/15/2002 Module 2 10

Much of the data that we record is historically related. The history of maintenance, for example, is needed to evaluate maintenance effectiveness, construction quality assurance and quality control data as well as acceptance testing as well as built records are needed for construction evaluation. Annual traffic records including growth and composition are important, finally accidents as they relate to location on the highway network, particularly, high risks sites and any counter measure or modifications that have been made. All are good examples of historically related parameters.

**Slide 11**

## Example of Use of Historic Related Data: Maintenance History

**Network Level**

a) Maintenance Programming

b) Evaluate maintenance effectiveness

c) Determine cost-effectiveness of alternate designs and treatments

**Project Level**

a) Identify problem sections

b) Estimate maintenance effectiveness

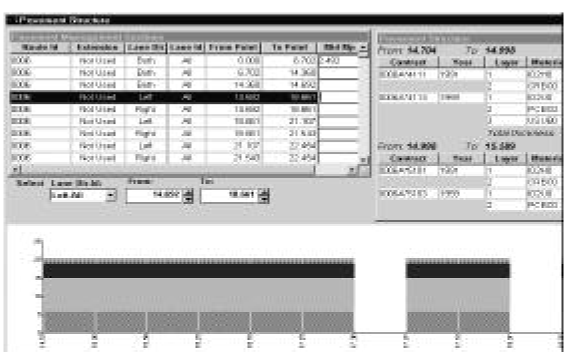
11/15/2002 Module 2 11

Maintenance history is one of the better known types of historic data used in pavement management. It is also one of the areas that many DOTs have been negligent in recording in the past. Unless the record of maintenance performed is recorded in the database including the location and the amount of the maintenance, this historical data can then be used at the network level for maintenance programming, evaluating the effectiveness of the maintenance that has been performed, as well as determining the cost effectiveness of alternate maintenance designs and alternate designs. Those that have required more maintenance than others for example.

At the project level, maintenance records can be used to identify problem sections, those which require an abnormal amount of maintenance, as well as providing individual information of a more detailed nature about maintenance effectiveness.

**Slide 12**

## PennDOT Structural History Review



Example of use of Historic Related data by PennDOT:

For review of structural history data for any section in network,

To view structural cross sections along the road or a project

Each material in database has a different color

All thicknesses are identified

Reports with all necessary information are easy to print.

**Slide 13**

## Importance of Construction & Maintenance History Data

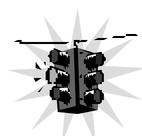
- Must have as-built data for
  - Performance modeling
  - Assessing construction quality
- Maintenance history
  - Affects performance
  - Evaluate effectiveness

11/15/2002 Module 2 13

To fulfill its purpose, a PMS must follow through from planning & design to construction and periodic maintenance.
Loss of performance, eventually leading to need for rehabilitation, is identified within ongoing process of data collection and evaluation. Evaluation of pavement performance is also used for determining current status of pavement network.
Essential to model development is data on construction and maintenance. Pavement maintenance data includes records of all maintenance activities that can affect performance such as crack sealing, patching, and surface seals. A high level of maintenance makes it possible to extend life of the pavement beyond the expected design life.

**Slide 14**

## Consistency in Pavement Evaluation Data



- Objective evaluations
  - With calibrated instruments
  - Or well-trained evaluators
  - Explicit instruction on survey methods
- Consistency across time and space

11/15/2002 Module 2 14

When evaluating existing pavements consistent and repeatable condition data is essential requirement. Many pavement evaluation schemes rely on judgment of a human rater, or different groups of raters. These often lack uniformity and lose meaning over time as attitude and ability of raters change and/or new personnel are added. Whenever possible, evaluation should be performed objectively using calibrated instruments. The problem is even more acute when data are examined across time to evaluate pavement performance.
Thus, engineering evaluation of pavements requires well-documented set of practices and procedures, plus good training. Observers should be given explicit instructions on survey methods.

**Slide 15**

## Standards for Network Level PMS Data Collection

- Data consistency nationwide desirable
- FHWA research project in 1996
- Standards for collection of cracking, rutting, faulting and roughness
- Examined or adopted as AASHTO Provisional Standards
- Many benefits for PMS Engineering Analysis

11/15/2002 Module 2 15

To improve data consistency on nationwide basis, FHWA recently completed a major research project that developed network-level PMS data collection protocols in the area of cracking, rutting, faulting and roughness measurements. To achieve uniformity, developments considered practices within critical state DOTs, extensive LTPP studies and adjustments necessary to facilitate data collection by modern automated equipment. The results are being carefully examined by AASHTO as Proposed AASHTO Provisional Standards (PAPS) for application at the state level. This project concentrated on developing standards at network level, because this constitutes largest data collection area in PM and most costly due to its size.

**Slide 16**

## Pavement Management Sections

- Permanent location reference
- Cross referenced for all other systems and uses
- Dynamic segmentation
- Data aggregation

11/15/2002 Module 2 16

PMS must use a permanent referencing system to identify pavement sections within the network. Location methods used by other divisions should be changed or cross referenced. Highway agencies frequently have multiple methods of referencing pavement sections. Historically, different sections or divisions have data collection and have needs that are not totally compatible with needs of other divisions. For example, the planning section may use traffic control sections for the collection and storage of traffic data; the construction section may use a construction project numbering scheme; and operations may use a route mile-post method for scheduling maintenance operations. A PMS needs to coordinate these functions.

**Slide 17**

## Data Integration & Centralization

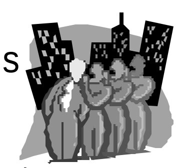
- Electronic Data essential
- Integrated Systems
- Integration Methods and Tools
- Analysis of Database
- Statistical Analyses required

11/15/2002 Module 2 17

For data to be really useful in an engineering analysis sense and for good network analysis it is essential that the data be integrated or at least centralized to some degree. It is important to put the data in an electronic format. Data stored in flat files or other hand written methods can not be used effectively. It is essential to have integrated data as well as integrated methods and tools fraternizing the data and of course an analysis of the database particularly statistical analysis is required if the data is to be useful for engineering applications.

**Slide 18**

## Integrated Systems



- Shared data
- Location referencing standards
- Traffic information
- Condition status
- Work programs
- Maintenance needs and effects

11/15/2002 Module 2 18

Any integrated data system will have the information and aspect s hown in the six items listed in the slide. The instructor should review these items and point out to the class the importance of each.

**Slide 19**

## Integration Methods & Tools

- Integrated Data
  - – Shared data across organization
  - – Multiple location cross-referencing
- Integrated Data base(s)
  - – Centralized data base
  - – Distributed (replicated) data bases

11/15/2002 Module 2 19

Note the difference between Data and Database Integration only achieved with adequate commitment throughout organization. Commitment only after benefits can be demonstrated and quantified. It is essential that the instructor clarify for the class participants the importance of demonstrating to the users of the database and the people who put the data in the database that the data will be used if properly stored and quantified. Historically, many agencies have not made it clear to the people providing the data just how important the data is. Therefore, inadequate attention is given to actually providing good data into the database.

**Slide 20**

## Analysis of Database / Data Mining

- Supplement with additional data
- Organize and cleanse PMS data, provide in format ready to use
- Evaluate suitability of data base
- Statistical Analysis

11/15/2002 Module 2 20

Data mining means reviewing existing data, taking a new look at subsets of data and determining what information might be available that has previously been overlooked. One of the important steps is plotting data in various categories; if pattern emerges it should be examined. There might be a strong pattern but lots of scatter. In this case, it is necessary to list other factors which could affect results.
Additional data from MMS, lab reports, field testing, etc. Cleanse, e.g. by removing obvious outliers and suitability of database also governed by significance of data, for that statistical analysis essential.

**Slide 21**

## Statistical Analyses

- Deterioration/road performance curves
  - – Statistical - Regression Analysis
    - Least squares, Linear regression, Non-linear models
  - – Probabilistic - Transition Probability Matrices
    - Markov transition process
- General data - aggregate results
  - – Percentiles, Mean, Mode, Median, Variance, ANOVA, F-test, Standard deviation, Coefficient of variation, R-square, etc.

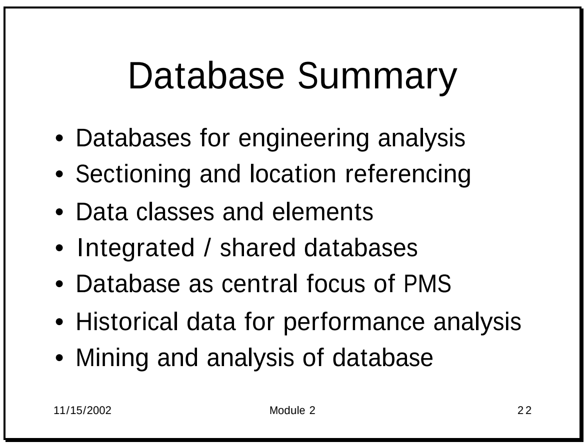
11/15/2002 Module 2 21

Markov process is time-dependent stochastic description of event development. Transition probability is defined as probability that variable (e.g. PI), starting in one condition state (e.g. very good) will be in another condition state (e.g. good) after specified time. Matrix is formed by condition state versus time.

- Least squares: Line with smallest sum of squared vertical prediction errors (used as best predictive line through data)
- Percentile: expressing ranks as % from 0 to 100
- Mean or average: sum of the scores divided by their number
- Mode: most frequent score in distribution
- Median: midpoint in distribution, point above & below which half of scores fall
- Variance: mean of squared deviation scores about mean of distribution
- ANOVA: Analysis of Variance - statistical hypothesis testing based on examination of different sources of variability in complex situation
- F-test: ratio of two variance measures used to perform each hypothesis test

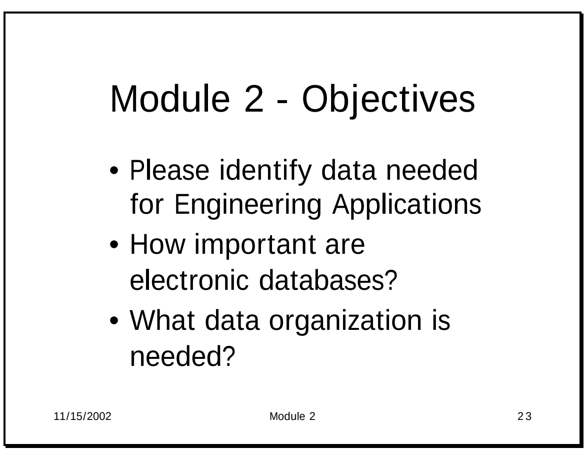
- Standard deviation: the square root of the variance
- Coefficient of variation: Standard deviation divided by average
- r-square: coeff. of determination (0 : no relation, 100 : all points in line)

**Slide 22**




The instructor should use this slide to summarize the module pointing out that each of these seven items listed on the database summary is important and that they have been covered in the module and will be extended in subsequent discussions. The instructor can use his own imagination and knowledge to wrap up the module in a meaningful way. Following this slide there should be ten to fifteen minutes of good group discussion, which will be led by the instructor.

**Slide 23**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. What is your involvement with a database (central or in your own group)?
2. Are you providing data or using them?
3. Do you have easy access to data that are important for your job?
4. What are the major concerns about databases in your agency?

# MODULE 3

# Superpave Performance Monitoring

# Module 3
# Superpave Performance Monitoring
# Instructional Time: 50 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

## Participant Questions

1. Let's get some feedback from somebody in construction, somebody in the lab/materials, somebody in design, and somebody with PMS as to their potential contribution to make performance monitoring easier.

2. Can you collect most of the needed data?

**Slide 1**

## Module 3
## Using PMS Data to Monitor Performance of Superpave

Study for FHWA by TRDI in 2000/2001 with input from:

- Maryland SHA
- Florida DOT
- Indiana DOT
- Arizona DOT
- Washington State DOT
- The University of Washington

11/15/2002 Module 3 1

Using PMS data to monitor performance of Superpave. This module describes an important engineering analysis study related to the use of PMS data to predict Superpave performance. The study was sponsored by FHWA and was carried out by Texas Research & Development, Incorporated through Battelle Institute during 2000 and 2001. Five states were involved as shown on the slide. At the end of the study, the University of Washington was helpful in providing a web based system for evaluating the data, which will be covered in detail.

**Slide 2**

## Module 3 - Objectives

- Illustrate how to use PMS to evaluate performance of new materials like Superpave and to validate new design concepts
- Evaluate experience of 5 states in collecting PMS-related data for analysis
- Outline support needed for state DOTs to do a proper analysis with compatibility of data among states
- Formulate a multi-state study

11/15/2002 Superpave Performance Monitoring 2

The objectives of Module 3 are to relate engineering analysis to an important problem that all state DOTs are facing at the present time. That is the application of Superpave in their agency. The information in this module is based on a project set up by the Federal Highway Administration to determine whether or not data existed in various state highway departments which could be used to evaluate SuperPave and to prove whether or not SuperPave was fulfilling its objectives. The module will improve the participant's comprehension of data requirements for major engineering analyses and will show how five state DOTs have approached the problem and what needs to be done as the next step. Finally, the module should spark the participant's interest in evaluating Superpave benefits within their DOT. The objectives of the project are listed in this slide and should be covered by the instructor.

**Slide 3**

## Phase 1 – Collecting Information & Recommendations

from Maryland SHA, Florida DOT, Indiana DOT, Arizona DOT and Washington State DOT

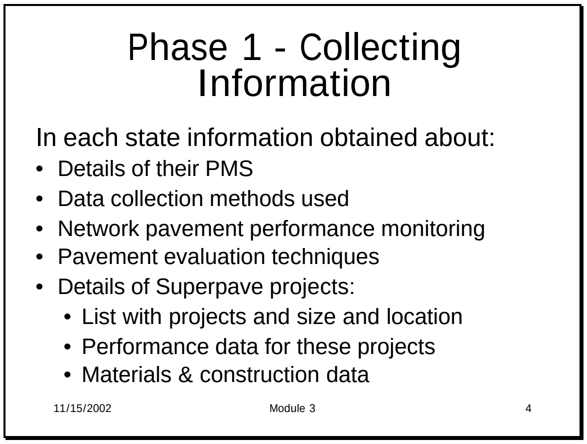
## Phase 2 – Pathfinder Study

in Maryland SHA with help of the University of Washington

11/15/2002 Module 3 3

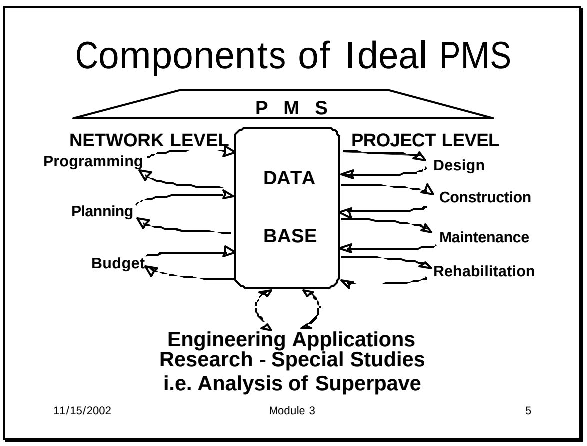
The project had two phases, the first phase involved collecting information and making recommendations from five state DOT's. The instructor can read the five names from the slide. After the recommendations were made, FHWA decided to extend the project to phase 2, a Pathfinder study to work with an individual state DOT,(in this case Maryland DOT) to show them how their pavement management data and their SuperPave data could be organized for proper analysis. The University of Washington cooperated in this phase of the study, led by Dr. Joe Mahony and his staff.

**Slide 4**



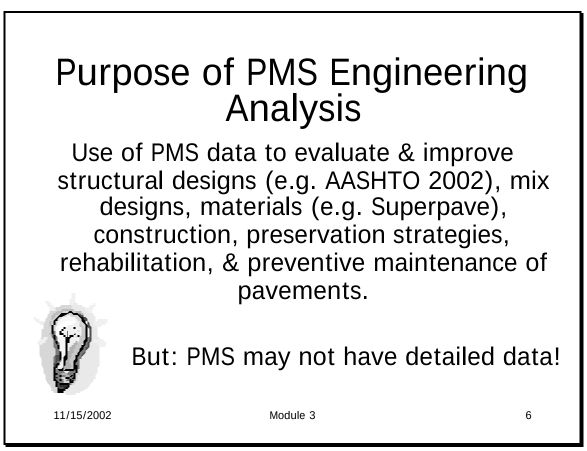

This slide covers the activities that were carried out in each of the six states visited. The instructor can look at the bullet points and expand on them in the discussion. The instructors are urged to read the review material on this module well in advance of preparing for this presentation.

**Slide 5**




This slide illustrates that a database is the central part of the pavement management system. It is not a pavement management system but it is essential to one. The three major categories that utilize the database, work at the network level, at the project level and engineering applications or research using the data from the database. This module deals with this third aspect of the use of pavement management data. Pavement management must be capable of being used in whole or in part by various technical and administrative levels of management in making decisions regarding both individual projects and an entire highway network. All functions are essential, but not all functions need to be active at the same time. In planning future construction consider individual project design in only an approximate way. A PMS can be viewed as a set of connected modules or "building blocks."

**Slide 6**




The purpose of engineering analysis in this situation is to evaluate the performance data from a pavement management database and compare that with materials data, however it’s clear from the states that were visited in the study that not all states have the detailed materials data in their pavement management database that is needed.

**Slide 7**

## Sources of Engineering Data other than from PMS database

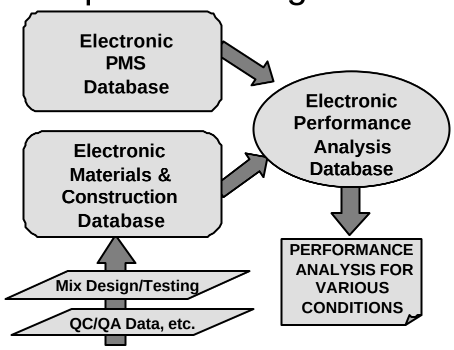
- Research data files,
- Construction records,
- Mix design and testing records,
- Additional field evaluations,
- Project plans,
- Pavement design data,
- Additional structural evaluation and/or materials testing,
- Maintenance Management Systems.



In many cases, the engineering data needed for analysis such as material properties etc. is not available in the computerized database. That data is available from several sources as indicated in the slide. The instructor should read the 8 bullet items outlined on the slide and expand on those based on those based on his reading of the background source material for this course.

**Slide 8**

## Concept for Linking Databases




The work of this project pointed out that while some of the information for the analysis was available in the electronic PMS database, other information was only available from laboratory t ests and other sources as shown in the previous slide. The project pointed out that this information has to be converted into an electronic materials and construction database. This combines with the electronic PMS database, and then provides the information needed for an electronic performance analysis. This analysis can then be performed for various conditions as illustrated in this slide.

**Slide 9**

## Current Limitations (1 of 2)

- In most cases materials, construction, and maintenance data not now tied to PMS data.
- Most agencies store materials and construction data in flat files, so transfer and analysis of data difficult.
- Not all relevant data recorded (e.g. in-place thickness often missing).
- Linking materials and construction data to an exact location normally not possible.



This slide points out some of the limitations that were found in current data from state DOTs and it lists four of the eight limitations that were found in this study. The instructor should review the items from the slide and discuss it based on his reading of the source material.

**Slide 10**

## Current Limitations (2 of 2)

- Performance data often averaged over a mile. Distress often sampled over short distances, e.g. milepost only. Normally only one lane measured.
- Therefore, difficult to link performance data to materials and construction data.
- Maintenance activities, if not properly recorded and referenced, could distort analysis.
- DOTs need time to implement new approach in existing structures.

11/15/2002 Module 3 10

This slide points out four more limitations that were determined in this study. The instructor should review these four limitations from the slide based on his reading on the background source material. Discussion should follow as needed.

**Slide 11**

## Desirable Components of Electronic PMS Database

- **Common referencing needed with Project Number, exact Location & Date**
- Climate and Traffic (ESAL and ADT) Data
- Age of original pavement & last rehab date
- Details of existing pavement structure
- Performance Data for various distresses linked to exact location (mile post or GPS, Lane and Direction).

11/15/2002 Module 3 11

Common referencing is critical for any electronic database. This needs to include project number, exact project location, dates etc. The slide shows four kinds of information that should be included in this electronic database. The instructor can discuss that based on his experience and his reading of the source material.

**Slide 12**

## Desirable Components of Electronic Materials and Construction Database

- **Common referencing needed with Project Number, exact Location & Date**
- Mix data, as designed and in-place
- Layer thickness, designed and actual
- Other materials & construction details
- Effects of maintenance activities
- Batch/lot numbers linked to location.

11/15/2002 Module 3 12

Again, common referencing is essential. In this case, it must be common with the referencing used in the PMS performance database. It should be emphasized by the instructor that this is absolutely critical. Many, many times the data from one database is not properly coordinated with data from another database. Thus, any analysis carried out is erroneous. This slide goes on to list five classes of data that should be developed from any source and entered into the electronic materials and construction database. The instructor should discuss these based on his reading of the course material.

**Slide 13**



Using the common referencing from the previous two databases, a reference should be set up for the analysis database. Many people think that data can be used directly from various databases at the same time. In one sense, that is true but in reality that data must be pulled into an analysis database, checked, compared and cleansed to the point that the analyst is sure that the data is compatible. This slide points out that with the proper data brought from the proper sources into the analysis database, it is possible to analyze the data and produce various results of value to the state DOT. If this can be done in several states or if data could be collected on a compatible basis from several states then the analysis becomes even more powerful.

**Slide 14**



The instructor can review the five items listed in this slide, which outlines the possibilities for network analysis. They are straight forward and can be read directly from the slide aid itself.

**Slide 15**



This slide outlines three classes of project analysis possibilities. The instructor can review these three categories of analysis and present them for discussion with the class.

**Slide 16**

## Phase 2 Pathfinder Study

Pathfinder study in Maryland to:

- Establish what data are required to link performance to materials and construction data,
- Collect all relevant data and put these in electronic format, and
- Load these into web-based system for storage, linking, evaluation and reporting.

11/15/2002 Module 3 16

After the first states were visited an interim report was prepared, which pointed out that there was adequate data available in each of the six states visited but that the data for the materials and construction information was not in an electronic format. It was recommended that FHWA provide support for one or more state DOTs to see what is would take to transfer the appropriate materials and construction data into a database. That recommendation resulted in a Pathfinder study in Maryland DOT. This slide outlines the items carried out in the study and should be reviewed by the instructor.

**Slide 17**

## PMS in Maryland

- SHA highway network - 16,362 lane miles
- Approximately 10,000 directional miles monitored annually in outside lanes with ARAN vehicle for IRI, rutting and cracking.
- Reporting of cracking numbers still awaits interpretation of video images.
- Friction measured every 0.1 mile with ASTM skid tester.
- Superpave applied since 1995.

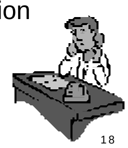
11/15/2002 Module 3 17

This slide summarizes very briefly the pavement activities carried out in Maryland, the pathfinder state. The instructor can review the five bullet points outlined. They are relatively complete and need not be repeated here.

**Slide 18**

## Elements of Pathfinder Study

- Maryland SHA agreed to provide PMS, materials and construction data in electronic format,
- University of Washington offered to put the MD data in their newly developed web based evaluation system,
- TRDI coordinated.



11/15/2002 Module 3 18

In this study, the Maryland State Highway Agency agreed to dig out the necessary information on materials and construction data for a number of projects. The project agreed to provide support for transferring that data into an electronic database. There were several considerations in this transfer. After considerable review it was determined that the University of Washington developed a reasonable Superpave database which could be used and they offered to enter the Maryland data into their newly developed web base data system. TRDI served as coordinator for this activity.

**Slide 19**

## Types of Data Needed for Analysis as Proposed by MDSHA

| QC/QA Data | | Mix Design Data | |
|---|---|---|---|
| 28 fields: | | 16 fields: | |
| Electronic: | 8 | Electronic: | 9 |
| Paper: | 16 | Paper: | 6 |
| Not available: | 4 | Not available: | 1 |
| **Pavement Design Data** | | **PMS Data** | |
| 11 fields: | | 16 fields: | |
| Electronic: | 0 | Electronic: | 9 |
| Paper: | 10 | Paper: | 4 |
| Not available: | 1 | Not available: | 3 |

11/15/2002 Module 3 19

This slide points out the types of data needed for analysis as outlined with the Maryland DOT. The information is divided into four quadrants: QC/QA Data, Mix Design Data, Pavement Design Data and PMS Data. The slide shows that they contained 28 fields, 16 fields, 11 fields and 16 fields respectively. In the QC/QA data, 8 were in an electronic format and 16 in paper format. Four of the desired fields were not available. For Mix Design, 9 were electronic, 6 in paper form and 1 not available at all. The Pavement Design Data, 0 were in electronic, 10 were on paper and 1 was not available. For the PMS data the majority 9 was available in electronic form, 4 on paper and 3 were not available.

**Slide 20**

## Difficulty of Data Retrieval in MD

| SUBJECT | SOURCE FILES | DIFFICULTY |
|---|---|---|
| PMS data | PMS data file | easy |
| Mix design | QC/QA database | easy |
| Mix QC and QA | QC/QA database | easy |
| Inventory Information | Project & Design | Medium |
| Density QC and QA | QC/QA database | Medium |
| Pavement Design Recommend. | Pavement design | Medium |
| Pre-overlay condition | Pavement design | Medium |
| Ride QC and QA | Construction | Hard |
| Daily & Project Paving | Construction | Hard |
| Binder & Aggregate tests | Various files | Unable |

11/15/2002 Module 3 20

This slide points out the difficulty that was found in retrieving data in Maryland. Ten subject data classes are outlined, the source files are given and the difficulty found in retrieving them is shown. The instructor can review this slide with the class and perhaps discuss with them what they think the difficulty obtaining the same information might be in their state.

**Slide 21**

## Website System with Superpave Data

- Developed by University of Washington, Dept. of Civil & Environmental Eng., in cooperation with WSDOT and NCAT,
- Currently used for data from DOTs of Washington, Missouri, Texas & Maryland,
- Acts as data warehouse, with sorting, viewing, linking, analysis and reporting capabilities.

11/15/2002 Module 3 21

This slide summarizes the website data system that was ultimately selected for use in the project. It was found out that University of Washington had already done a good bit of work in developing such a system. It was also considered that the AASHTO Superpave data entry forms might be used but Washington had already moved past this point and had a web based system which could be made available to any state. It was ultimately selected and Dr. Joe Mahoney and his staff were very helpful in agreeing to work with us. That database is currently used to some degree in the four DOT's mentioned above, Washington, Maryland, Missouri, Texas and Maryland. Finally, the data system can serve as the data warehouse, which can be used to sort, view, link, analyze and report.

**Slide 22**

## Advantages of Website System

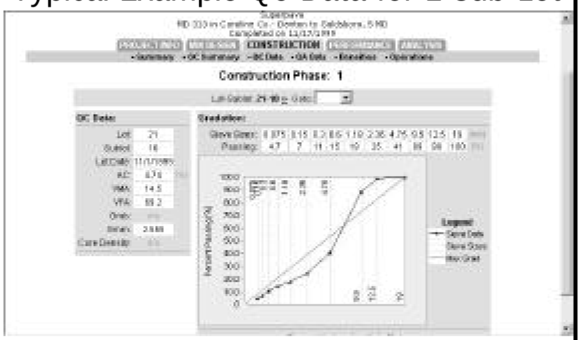
- Graphing and Summary functions
- Data export to Excel available
- Handles visual images (e.g. infrared)
- Flexible data presentation for each state
- Static GIS map location for each project
- Data immediately available to all users
- Easy to use data across projects or states

11/15/2002 Module 3 22

A number of advantages were found for the website system. Seven of those advantages are listed on this slide and need not be repeated here. The instructor should outline these seven advantages in his/her discussion based on his /her review of the background material provided. This should also lead to interaction and discussion with the participants as to how these advantages might fit into their DOT situations.

**Slide 23**

## Typical Example QC Data for 1 Sub-Lot

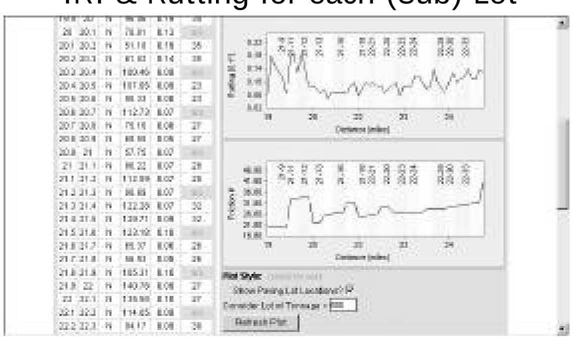



11/15/2002 Module 3 23

This slide illustrates a typical example of quality control data from a particular sub-lot in one section on Maryland 313, which was completed in 1993. Details of the lot and its location are shown on the left and a plot of gradation is shown on the right.

**Slide 24**

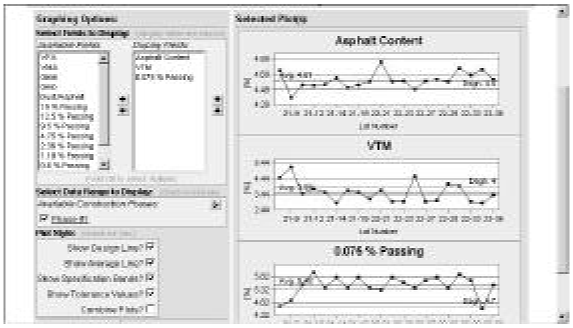
## Typical Example IRI & Rutting for each (Sub) Lot



This slide is a snapshot of the data in the database. On the left are shown numeric values at various points in the system and on the right, rutting and friction are plotted as a function of distance and miles.

**Slide 25**

Typical Example
Graphing Options for Volumetrics




This slide shows a graph of volumetric mix design information which illustrates the kind of information that is in the database and which can be used in the analysis.

**Slide 26**

Possible Evaluations At Network Level

- Binder content vs rutting,
- Fines (passing P200) vs rutting,
- IRI of several projects by year,
- Rutting of several projects by year,
- IRI vs use of Material Transfer Vehicle,
- IRI vs night/day paving,
- IRI vs surface preparation.

11/15/2002 Module 3 26

While there are other types of analysis that can be run, this slide points out seven types of analysis that can be run and were run in Maryland to illustrate the value of the system.

**Slide 27**

Possible Evaluations At Project Level

- IRI by year,
- Rutting by year,
- IRI vs distance/lots,
- Rutting vs distance/lots,
- IRI vs use of Material Transfer Vehicle,
- IRI vs night or day paving,
- IRI vs surface preparation.

11/15/2002 Module 3 27

There are also many kinds of analyses that can be run for individual projects. This slide points out several of those analyses and the instructor can review them directly from the slide and they need not be repeated here.

**Slide 28**

## Advantages of Concept for a DOT

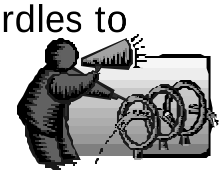
- Existing pavement network used as road test:
  - Evaluate different materials, techniques, design concepts, etc
  - Produce more accurate pavement prediction models
- Pavement preservation done more accurately
- Data entered only once, and data warehouse allows easy storage, retrieval, linking, analysis and reporting.

11/15/2002 Module 3 28

While there are many, many advantages of this concept of developing a complete electronic database, this slide points out three of the most important advantages. The instructor can read these advantages directly from the slide and they need not be repeated here. This should lead to some discussion with the group.

**Slide 29**

## Organizational Hurdles to overcome



- Resistance to change
- Lack of funds
- Fear for loss of control at group levels in DOTs
- Problems to standardize performance indices
- Fear that data are misused or that confidential data show up outside DOT
- IT Dept. might resist shift from Mainframes to Servers.

11/15/2002 Module 3 29

They say there is no such thing as free lunch and that is certainly true in building a good electronic database. There are always a series of organizational hurdles needed to be overcome. This slide outlines six such organizational hurdles. You may be able to think of additional hurdles in your DOT. The instructor can review these hurdles with the group and discuss the applicability of each to their own agency.

**Slide 30**

## Technical Hurdles to overcome

- Linking performance data to materials & construction data difficult because:
  - Performance data often averaged over a mile,
  - Distress often sampled over short distance only at each mile point,
  - Mostly only one lane measured.
- Maintenance activities, if not properly recorded and referenced, could distort analysis

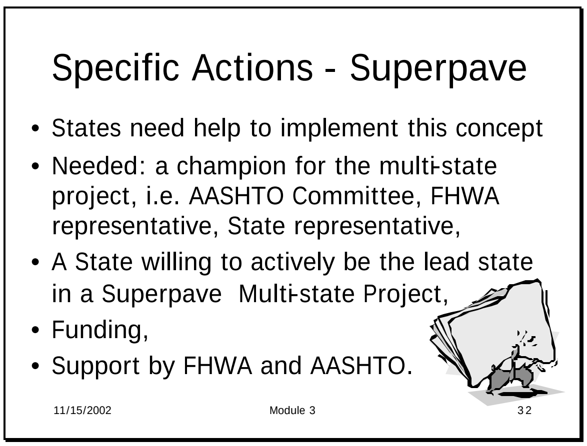
11/15/2002 Module 3 30

Of course, all of the hurdles found were not administrative and were instead technical. This slide outlines a number of technical hurdles that were found in the Maryland Pathfinder study. The instructor can read these items directly from the slide and they need not be repeated here. He/She should familiarize himself with this material and the text provided in the background document. This may lead to discussions with participants in the course based on whether or not these technical hurdles are applicable in their DOT.

**Slide 31**

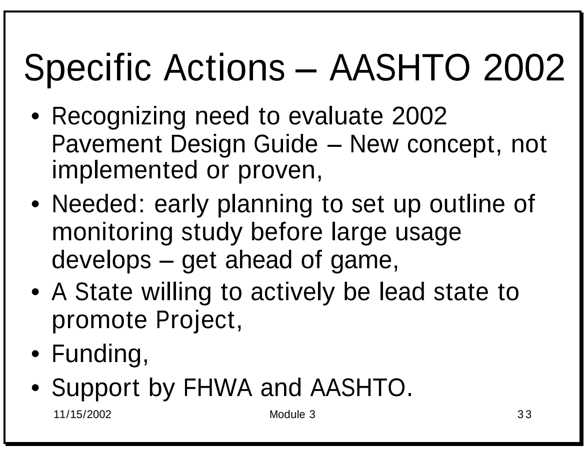

This slide comes from a picture found in Arizona DOT, which shows a dead possum in the middle of the road that was left when the paint stripe machine came by. This is the kind of thing we run into over and over. Little things which need to be removed from the database just as this possum should be removed from the road but is not and is “painted” over and becomes a part of the permanent scene to the detriment of all.

**Slide 32**



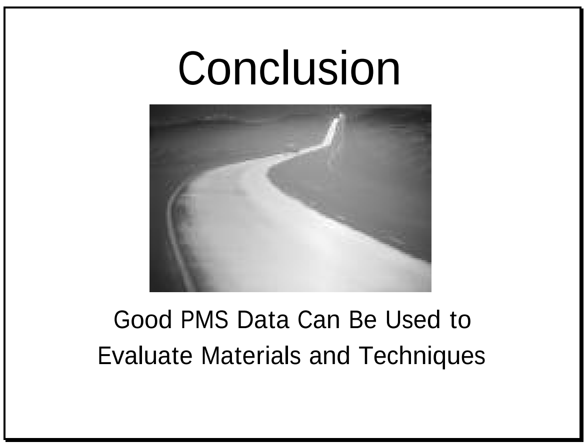

What kind of actions did the study show could be taken to make it possible to do the engineering analysis of Superpave? Is Superpave fulfilling the function for which it was intended? This slide outlines five major actions that are needed to make such a major study possible. Most importantly, it will be valuable if 10 to 20 states could combine their data in a national multi-state study. It is very important to find the state DOT that is willing to take the lead in such a multi-state study but none have yet come forward. Perhaps someone in this course would be willing to provide such leadership. The other specific items can be discussed by the instructor.

**Slide 33**



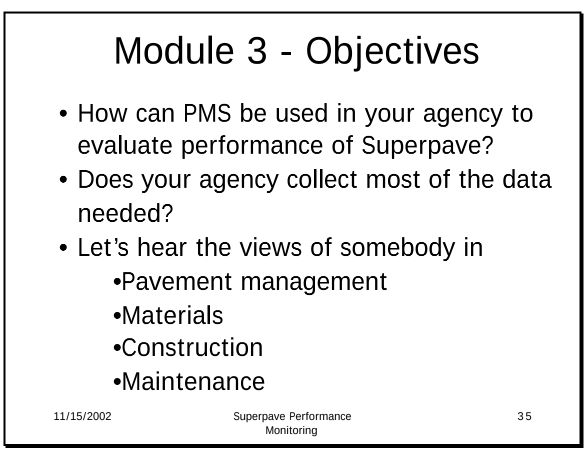

As most of you are aware, AASHTO is spending about $5 million to develop a new 2002 Pavement Design Guide. While this guide is being put together with a large number of complex mechanistic ideas and is being calibrated using some available data, it is far from proven because of its great complexity. Even if it is proven on the national level average, it will still have to be calibrated and adjusted for using in any individual state DOT. Engineering analysis using pavement management performance data and appropriate materials and structural thickness data could provide all the information that is needed for such an analysis. All of the limitations and requirements for good data outlined for the Superpave study would apply here. Good location referencing, good quality data, regular data collection etc. It will be very important to get this study initiated as soon as possible. Generally, we are always behind the power curve that sections are in service for five, six and ten years. As in the case of Superpave five years before any data is ever collected to begin the analysis. It is possible right now to get ahead of the power curve and set up such a study if we can find the lead state willing to support the study and if we can get necessary support from AASHTO and FHWA.

**Slide 34**




In conclusion, this study shows clearly that good pavement management data can be used to evaluate materials and other techniques if associated data is provided in electronic format.

**Slide 35**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant’s learning accomplishments.

1. Let’s get some feedback from somebody in construction, somebody in the lab/materials, somebody in design, and somebody with PMS as to their potential contribution to make performance monitoring easier.
2. Can you collect most of the data needed?

# MODULE 4

# Performance & Pavement Modeling

# Module 4

# Performance & Pavement Modeling
# Instructional Time: 55 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

## Participant Questions

1. How is your agency handling performance modeling?
2. Do you see possibilities for a better use of these techniques?
3. Are your prediction models generic, or tailored to your conditions?

**Slide 1**

## Module 4: Performance and Pavement Modeling

- Development of performance models from network data
- Pavement performance data and models used by PennDOT
- Pavement performance model curves used by WSDOT

11/15/2002 Module 4 P & P Modeling 1

Module 4 covers Performance Modeling plus 2 examples as outlined in this slide.

**Slide 2**

## Module 4 - Objectives

- Identify importance of performance models in network level pavement management
- Assess work on performance and pavement modeling
- Formulate the concepts
- Stimulate interest in performance modeling applications

11/15/2002 Module 4 2

The objectives of Module 4 are to identify for the students the importance of performance models in network level pavement management prioritization. It will give them an opportunity to assess work on performance and pavement modeling that has been carried out in Pennsylvania and Washington State DOT. It will further provide them a chance to formulate the concepts they will need to apply and should stimulate their interest in performance modeling applications.

**Slide 3**

## Pavement Performance Models

Obtaining good models for performance versus age or traffic loads is essential

- Performance generalized to mean deterioration or damage over time or traffic
- Pavement performance analysis is primary engineering application
- Includes analysis of effects and interaction of several parameters, mostly present in PMS database

11/15/2002 Module 4 3

Serviceability-performance concept, developed at AASHO Road Test, has been valuable and an important part of pavement technology since the 1960's. Development of good models for predicting performance, in terms of PSI or RCI versus age or accumulated axle load applications, has been a major challenge for pavement engineers. Engineering analysis to quantify effects on pavement deterioration and develop mathematical models that predict pavement performance over time. Material properties, environmental conditions, traffic volumes and loads, design type, construction quality, and maintenance levels all contribute to pavement deterioration and thus must be considered in performance analysis.

Despite the fact that performance had precise definition since Carey-Irick development of serviceability-performance concept, the term performance is often used in a loose way. Consequently, it has become common practice to use alternate terms such as deterioration or damage. This slide illustrates deterioration models. For past deterioration is used to predict future deterioration including an estimate of remaining service slide and application of an overlay to improve the performance index and then alternative rehabilitation future deterioration curves.

**Slide 4**

## Requirements for Performance Modeling

- Adequate database
- Inclusion of significant variables affecting deterioration
- Careful selection of functional form of model to represent physical real-world situation
- Criteria to assess precision of model

11/15/2002 Module 4 4

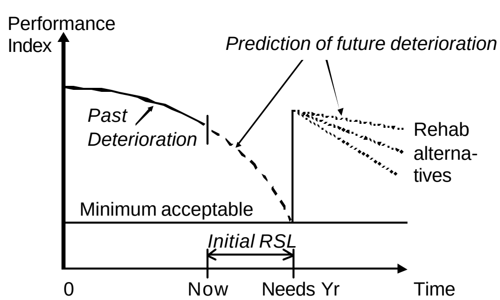
Adequate database:

- sufficient data points
- reliable information
- sorting, filtering and querying possibilities
- Significant variables: data on:
- distress
- environment
- traffic
- structure and sub grade

Functional forms to be discussed later. Criteria for precision: significance, statistical data.

**Slide 5**

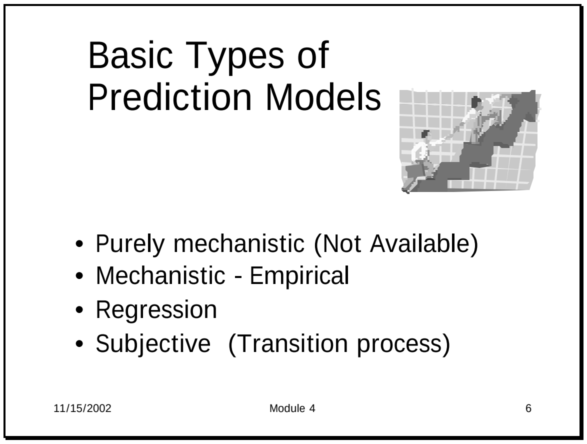
## Application of Deterioration Models




11/15/2002 Module 4 5

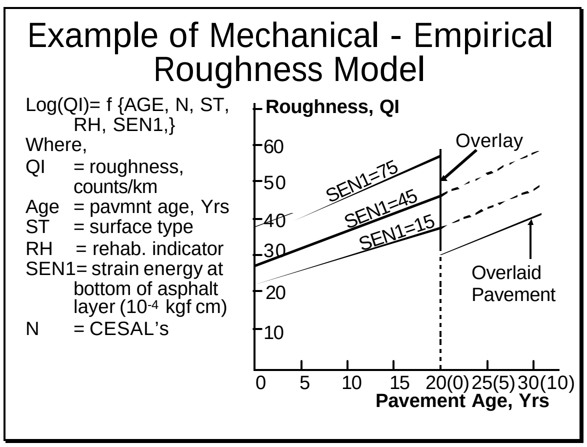
Example of deterioration models:
RSL = Remaining Service Life
This slide illustrates deterioration models. Past deterioration is used to predict future deterioration including an estimate of remaining service slide an application of an overlay to improve the performance index and then alternative rehabilitation future deterioration curves.

**Slide 6**



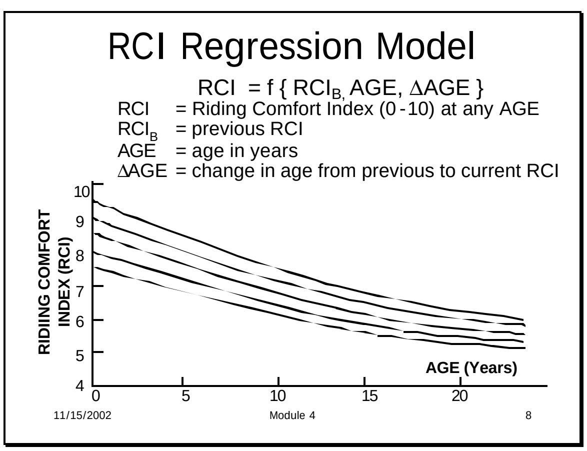

Purely mechanistic: based on primary response (behavior) parameter such as stress, strain or deflection. Such models have not yet been developed because “distress” is normally not a mechanistic parameter, properties of pavement structure, and loading conditions, are difficult to quantify in mechanistic terms.
Mechanistic - Empirical: response parameter is related to measured structural or functional deterioration, such as distress or roughness, through regression equations.
Regression: dependent variable of observed or measured structural or functional deterioration is related to one or more independent variables like subgrade strength, axle load applications, pavement layer thickness and properties, environmental factors, and their interactions.
Subjective: experience "captured" in formalized or structured way, using transition process models for example, to develop deterioration prediction models.

**Slide 7**




Example of mechanistic-empirical model for predicting roughness developed by Queiroz in ‘83, using linear elasticity in study of 63 flexible pavement test sections. Strain energy is mechanistic component in developed relationship.

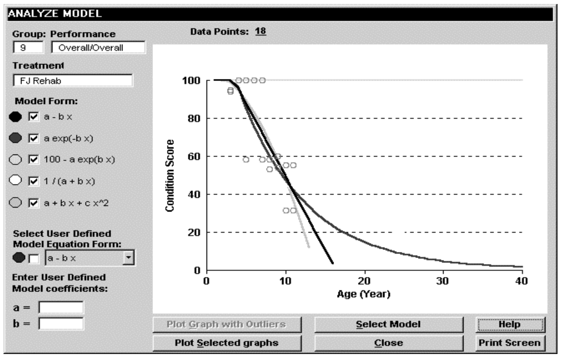
**Slide 8**




Example of regression model, no mechanistic elements. Developed from distress data in Alberta for conventional granular base pavements during 25 years. Regression analysis learned that only 4 quoted variables were significant.

**Slide 9**

## Regression with Visual Modeler




This slide gives an example of a typical regression that can be obtained from visual modeler which is a pavement performance modeling application program that was developed for PNDOT and the and the Federal Highway Administration at Texas Research & Development, Incorporated. It is a user friendly statistical analysis that allows the user to select from among five model forms or use their own defined model equation form. The references in the text will allow any members of the class to obtain the program and use it as they desire.

**Slide 10**

## Transition Probability Matrix for Markov Model

| Initial Condition State | Future Condition State | | | | |
|---|---|---|---|---|---|
| | Very Good | Good | Fair | Poor | Very Poor |
| Very Good | 0.90 | 0.10 | | | |
| Good | | 0.93 | 0.07 | | |
| Fair | | | 0.88 | 0.12 | |
| Poor | | | | 0.85 | 0.15 |
| Very Poor | | | | | 1.00 |



Example of subjective probabilistic modeling as used in Visual Modeler.

- Transition probability matrix defines probability that pavement in a certain condition state will transition to other condition state in one year.
- As shown in the table, the majority of pavements will stay in same condition state from one year to next, e.g., a “good” pavement has a 93% probability of remaining in same condition after one year.
- One of the requirements of transition probability matrix is the sum of each row must equal 1.0. Formal interview methods, such as Delphi method, can be used for developing matrices. The experts are asked to determine the probability a pavement in one of condition states will go to a future condition state in one time period.

**Slide 11**

## Other Factors that Affect the Transition Matrix

- Pavement type
- Pavement thickness
- Traffic volumes and loads
- Subgrade type or strength
- Environmental and regional effects



Because the Markov process estimates future condition state solely from current condition state, other factors that affect pavement behavior are handled by defining a transition matrix for each combination of factors that affect pavement performance, such as these:

- Pavement type
- Pavement thickness
- Traffic volumes or loads
- Subgrade type or strength
- Environmental and regional effects

**Slide 12**

## Use of Performance and Design Models for Engineering Analyses

- Models create possibility to predict performance over time in measurable terms
- In examples in remainder of course performance & design models are featured in several ways.

11/15/2002 Module 4 12

This slide summarizes the use of performance models for engineering analysis and sets the stage for the next portion of Module 4.

**Slide 13**

## PennDOT's Engineering Analysis Elements

- Module 4:
  - Overview of PennDOT PMS
  - Pavement performance data & modeling
- Module 9:
  - Techniques for selecting pavement rehabilitation strategies

11/15/2002 Module 4 13

The next portion of this module will describe some of the engineering analysis elements of the PennDOT PMS. We will first present a brief overview of the PennDOT PMS so that the students can understand how it fits together. The instructor should deal with the pavement performance data and modeling aspects of visual modeler used by PennDOT.

This slide also points out that a later application of PennDOT Engineering Analysis will be presented in Module 9. That is their techniques for selecting pavement rehabilitation strategies.

**Slide 14**

## PennDOT's Roadway Management System (RMS)

- STAMPP - PMS
- BMS - Bridge
- PRMS - Project
- MORIS - Maintenance
- ARS - Accident
- FMIS - Financial
- CMS - Construction
- CAMS - Construction & materials
- GIS - Geographic

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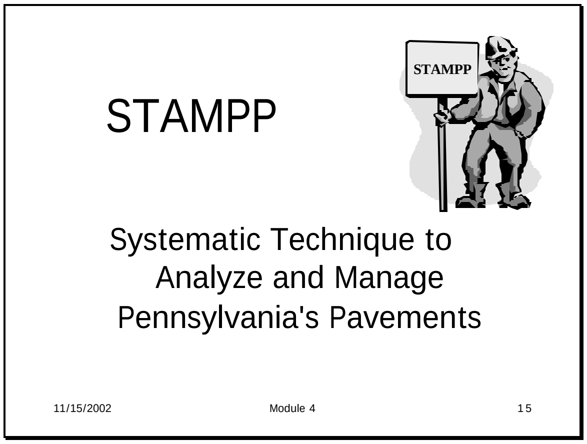
The RMS serves a highway network that has 4,300 miles on the National Highway System and 41,000 miles of other highways. This system provides the primary input for developing an annual construction and maintenance program of $1.75 billion.

STAMPP is PennDOT's pavement management information system.

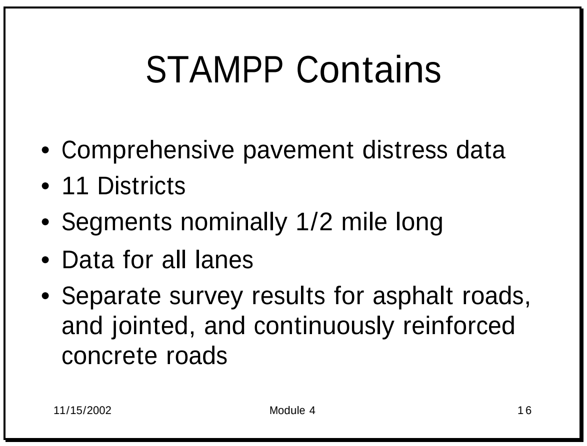
There is a list of eight other systems starting with BMS and ending with GIS, which the instructor should describe very briefly as being part of the overall roadway management system used by PennDOT.

**Slide 15**



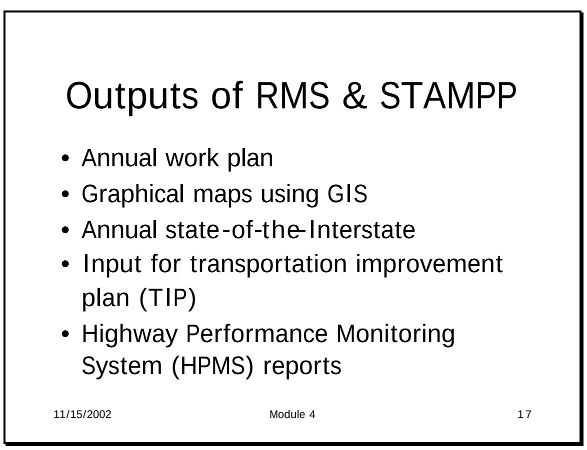

The pavement management system known as STAMPP has a mainframe data-base.

**Slide 16**




STAMPP is a comprehensive distress database that contains data for eleven districts. Segments are nominally ½ mile long although they may vary depending on other factors. In general, data is provided for all lanes in each of the pavement segments. Different survey techniques are used for asphalt vs. jointed or continuously reinforced concrete pavements.

**Slide 17**




- Annual work plan with information on pavement distress, guide-rail conditions, traffic and allocation of maintenance funds.
- Graphical maps showing pavement condition and needed projects in a county, district, or state.
- Annual State-of-the Interstate Report with pavement condition and roughness data, and detailed traffic-count data from RMS to analyze current and projected rehabilitation needs of Interstate system.
- Metropolitan and PennDOT's planning organizations use PM data to develop their multiyear transportation improvement program (TIP).
- PennDOT produces Highway Performance Monitoring System reports which are submitted to FHWA using RMS and STAMPP data.

**Slide 18**

## Distress Data Collection

- Annual survey 26,000 center line miles, all NHS and half of other roads, May - Sept.
- IRI with S-Dakota style profilers
- Up to 1996 - manual distress survey by 200 college students with quality audits
- Since 1997 - contracting for automated data collection, reasons:
  - Lower cost, particularly for training and travel
  - Exposure of raters to traffic
  - Variation in data between teams

11/15/2002 Module 4 18

The information on this slide is self evident and the instructor should familiarize her/himself with it and present it in his own words as the students review the slide itself.

**Slide 19**

## Distress Scores

- Distress/condition measures are converted into distress scores with 0 -100 scale
- Distress scores calculated based on type of distress using either a distress converter or a maximum allowable extent algorithm
- Then performance indexes are weighted combinations of selected distress scores

11/15/2002 Module 4 19

The information on this slide is self explanatory and the instructor should describe the three items in his own words trying to provide general background information to the audience.

**Slide 20**

## Combination of Distresses into Performance Indexes

- User selects distresses to include in each performance index (PI)
- Each included distress is weighted by user defined factor
- The weights are then used in multiplicative index calculation algorithm to produce final performance index scores

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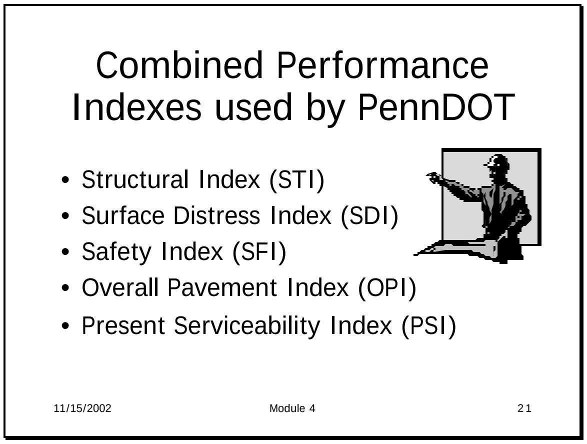
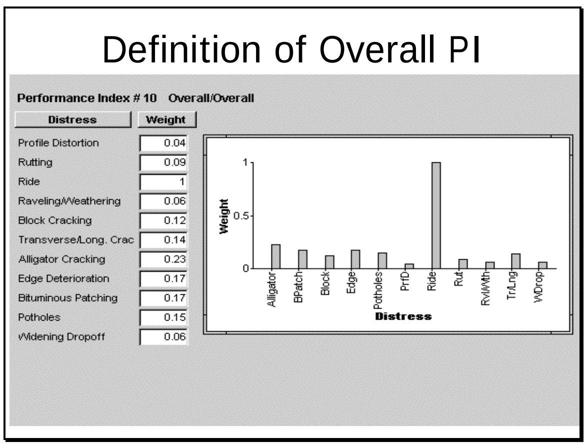
PennDOT uses a lot of flexibility in combining its distresses into performance indexes. As in many states, various types of distresses are combined into a single distress or performance index. The user has the flexibility to select the individual distress and also to select the weights for them.

**Slide 21**



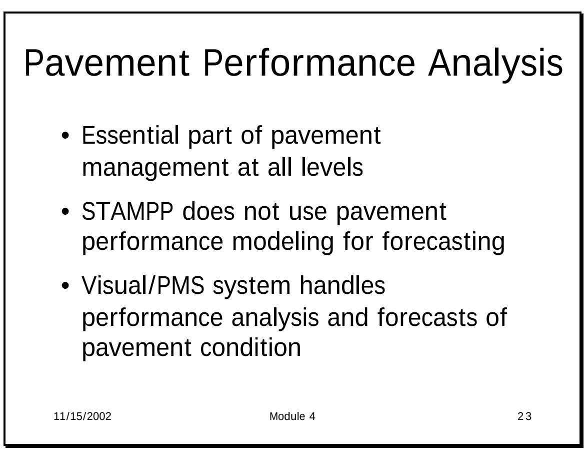

Here are five combined indexes that are used by PennDOT including structural index, surface distress index, safety index, overall pavement index and present serviceability index. One additional thing that needs to be considered is the fact that for project level work, a project may consist of several segments in the database. When that is the case, the individual indexes for each of the segments are all added up and averaged over all the segments to get a project index value.

**Slide 22**



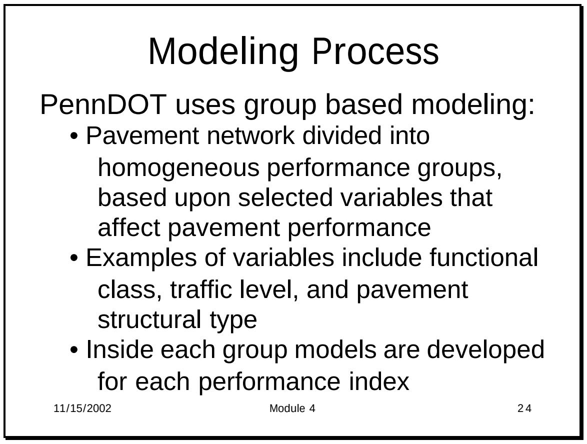

This slide lists the weighting factors that are used in the overall performance index in many of PennDOT's applications. As can be seen the ride value of 1.0 far outweighs the other performance indicators. The second largest index weighing function is .23 for alligator cracking.

**Slide 23**




Pavement performance analysis is an essential part of pavement management at all levels. Currently, the PennDot STAMPP program does not use pavement performance modeling for forecasting. At least this was true as of 1999. Subsequently, a Visual PMS System has been installed in Pennsylvania which does do performance analysis and forecasts future pavement conditions.

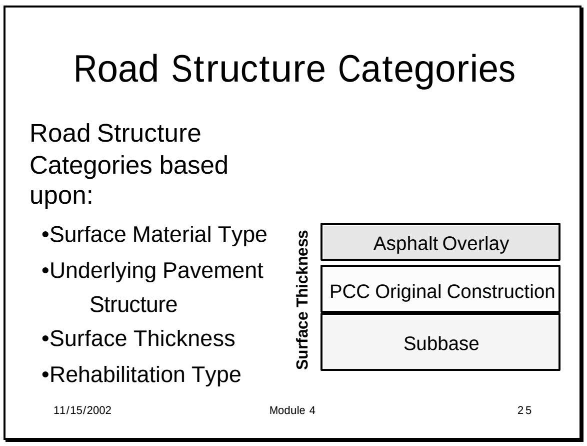
**Slide 24**




In its performance modeling process, PennDOT uses group based modeling. The pavement network which is divided into homogeneous performance groups that is sets of pavement segments that are known from past history to perform similarly and have similar basic variables such as sub-grade type, climate etc. Other examples of variables used to set up modeling groups include functional class, traffic level and pavement structural type

Once a group is set up, models are developed for each performance index for all the data within that individual group.

**Slide 25**

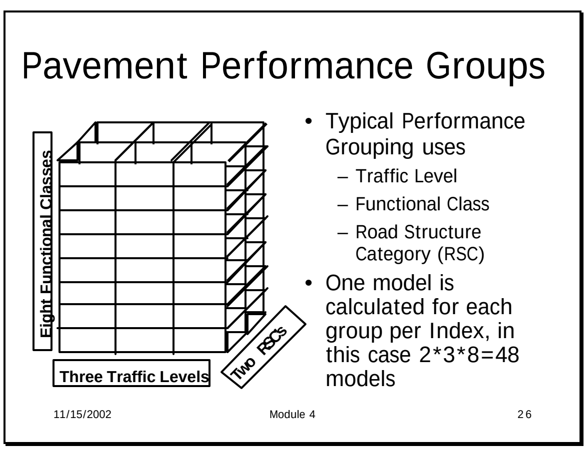



Road Structure Categories usually defined by combination of four factors:

1. Pavement surface material type (asphalt concrete or cement concrete).
2. Underlying pavement structural makeup
3. Pavement surface layer thickness.
4. Rehabilitation type or code that indicates whether pavement is overlay of existing pavement structure or newly constructed pavement.

For example, typical RSC used in PennDOT is “Thick ID2 over PCC”. This category indicates that the pavement surface is thick, its material type is ID2 (this is a particular asphalt mix as defined by PennDOT design specifications), and it is an overlay of a plain jointed cement concrete pavement.

**Slide 26**




Example of formation of 48 Performance Group Models from 8 functional classes (e.g. road types), 3 traffic levels (e.g. AADT levels) and 2 RSC’s (e.g. asphalt and concrete).

This matrix defines the 48 combinations of factor levels which define the groups to be modeled.

**Slide 27**

## Model Building and Review

- Most modeling systems allow building two types of models:
  - Regression based - Deterministic
  - Transition probability based - Probabilistic
- Models are built for pavement groups using both linear and non linear equations

11/15/2002 Module 4 27

Visual/PMS™ allows the user to plot raw data along with models built by regression modeling module, analyze data with outliers, and select best model. Sometimes, models built from available data may not be realistic. A practical tool is provided to determine whether models can be used or adjusted, in addition to a test of statistical significance. In some cases, when models can not be obtained due to lack of data, they can be developed subjectively based on available models with similar modeling criteria and engineering judgment.

**Slide 28**

## Deterministic Models based on Regression Equations

**Four regression forms are available**

| # | *Model Form* | *Transformation* |
|---|---|---|
| 1. | $y = a + bx$ | None |
| 2. | $y = 100 - a(e)^{bx}$ | $y' = \ln(100 - y)$ |
| 3. | $y = a(e)^{-bx}$ | $y' = \ln(y)$ |
| 4. | $y = 1 / (a + bx)$ | $y' = 1 / y$ |

y = Performance Index
x = pavement age
a, b are regression coefficients

11/15/2002 Module 4 28

Steps for building regression models are:

1. Prepare set of data for Y (condition index) and X (pavement age) from the performance master file;
2. Transform Y (for Model Forms 2 through 4);
3. Run regression analysis without removing any data points;
4. Identify outliers (all $(Y_i - \ddot{y})/ SD \geq 3$, i = 1, 2, ..., (SD = standard deviation);
5. Remove all outliers from the data set and run regression analysis again, if desired.

**Slide 29**

## Probabilistic Models based on Transition Probabilities (Markov)

Transition probability matrices can be produced from the calculated regression equations with Visual Modeler

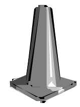
11/15/2002 Module 4 29

Probabilistic models are presented in matrix form. Each cell of matrix represents a transition probability or the probability that a pavement section will transition from one condition state to another in a given amount of time, usually one year.

**Slide 30**

## Modeling Example

- Model built for overall pavement index
- Road structure category: Pennsylvania FJ asphalt overlays of existing asphalt pavements
- The performance group is:
  - high traffic (AADT>3250)
  - NHS urban roadways
- 18 data points were available for analysis

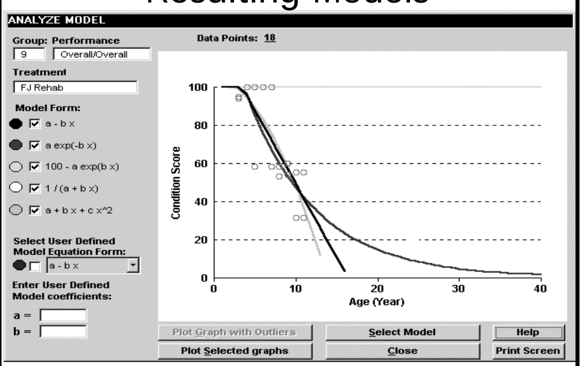




This slide covers 4 detailed elements, which the instructor should review with the class.

**Slide 31**

## Resulting Models




Initial plot of 18 data points along with all available model forms are shown. The left side of the graph defines the model forms that are available. Five separate possible curves are plotted through the data (See Reference Manual for a larger print). You can see that the predicted life varies with the model type.

**Slide 32**

## Model Selection

MODEL SELECTION

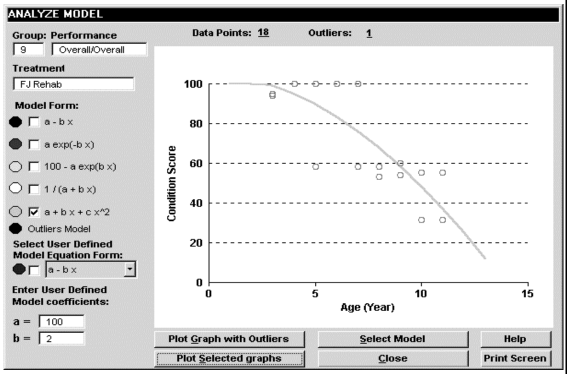
| Model Form | Outliers Removed? | Model Equation | Record Number | Outliers Number | St. Error | R^2 | Mo Sta |
|---|---|---|---|---|---|---|---|
| a + b x | No | 127-7.75833T | 18 | 0 | 15.5 | 0.65 | Re |
| a + b x | Yes | 127-7.75833T | 18 | 0 | 15.5 | 0.65 | Re |
| a exp( b x ) | No | 155.48352exp(-0.11875T) | 18 | 0 | 16.6 | 0.64 | Re |
| a exp( b x ) | Yes | 155.48352exp(-0.11875T) | 18 | 0 | 16.6 | 0.64 | Re |
| 100 - a exp( b x ) | No | No model | 18 | 0 | 0 | 0 | |
| 100 - a exp( b x ) | Yes | No model | 18 | 0 | 0 | 0 | |
| 1/( a + b x ) | No | 1/(0.0019+0.0019959916T) | 18 | 0 | 20.3 | 0.58 | Re |
| 1/( a + b x ) | Yes | 1/(0.0019+0.0019959916T) | 18 | 0 | 20.3 | 0.58 | Re |
| c + bx + ax^2 | No | 106-0.78106T^1-0.49837T^2 | 18 | 0 | 15.2 | 0.67 | Re |
| c + bx + ax^2 | Yes | No model | 17 | 0 | 0 | 0 | |
| User Defined | No | 100-2T | 18 | 1 | 0 | 0 | Use |

Ok Cancel

Six different models, with and without outliers removed are shown.
Lowest standard deviation and highest r^2 resulted for polynomial model y=c+bx+ax^2, with no outliers removed. See also next slide.

**Slide 33**

## Plot of Selected Model




Plot of polynomial model with highest R^2 is shown here. This model can be saved for use in other parts of PMS software as needed.

**Slide 34**

## Washington State DOT's Engineering Analysis Elements

- Module 4:
  - Overview of WSDOT PMS
  - Pavement performance modeling
- Module 5:
  - SCOPER overlay design methods



This is a list of the sub-modules for WSDOT. Washington State DOT was very helpful in providing information for this course and have done a considerable amount of engineering analysis. Results of their work are presented in Module 4 and Module 6. Beginning with the next slide, an overview of the Washington PMS will be presented so that you will know more about how they operate. This will be followed by a discussion about pavement performance modeling as they use it. Later in Model 6, Scoper will be discussed in terms of the way it is used for overlay design methods. The instructor can read from the material on the slide, which outlines the details to be presented and describes the basic concepts of the Washington State PMS. Four major points are made here. The process is continued on the next slide.

**Slide 35**

## Overview of WSPMS (part 1)

- Developed pavement condition survey program in mid '60's for setting priorities
- In late '70's, first WSPMS was developed
- Condition surveys every two years since '69 and every year since '88
- 1988 programs rewritten to fit mainframe file structures and to work in a local area network with PC's



The instructor can read from the material on the slide, which outlines the details to be presented and describes the basic concepts of the Washington State PMS. Four major points are made here. The process is continued on the next slide.

**Slide 36**

### Overview of WSPMS (part 2)

- Problems with worst-first programming as budget estimates proved inaccurate
- In 1993 Legislature required Life Cycle Cost Analysis to prioritize rehabilitation projects
- Major update implemented to include Pavement Structural Condition Index and Project Scoping technique

11/15/2002 Module 4 36

This slide continues the description of the overview of the Washington State PMS. Problems with worst-first programming: Once a preliminary program was setup, based on initial budget estimates, WSDOT developed Capital Preservation Budget. Then individual projects were sent forward for pavement design. By this time a program was already set and money available for an individual project had been predefined. This situation created problems because often the money budgeted for a specific project was inaccurate. Generally not enough money was programmed and in some cases excess money was provided.

**Slide 37**

### Overview of WSPMS (part 3)

- Eliminated worst-first programming
- PMS now predicts "due year" based on historic, condition & structural data and deterioration models
- Graphical displays provided in user-friendly environment
- 1995 update to Windows, conversion of files to ACCESS database

11/15/2002 Module 4 37

After Washington developed experience with their system they eliminated worst first programming methods and they now predict the year in which rehabilitation or major action is to be taken. This is called the "due year". It is based on historic condition and structural data as well as deterioration models that they have developed. Graphic displays are provided in user friendly environment and in 1995 the methods were updated to a Windows format and the files were converted to an Access database. This slide outlines four major components of the Washington State PMS: file building that organizes several large databases used in the PMS system, and interpretation program that is used to interpret and provides specific information on 3200 pavement sections statewide, a project level analysis is used as an optimization program for project selection and finally a network level analysis module is used to help ensure the best overall condition will be produced for the state pavement network for the fixed level of funding available.

**Slide 38**

### Components of WSPMS

- File building
  - Organizing several large data bases
- Interpreting program
  - Specific info on 3,200 sections statewide
- Project level analysis
  - Optimizing program for project selection
- Network level analysis
  - Ensuring best overall condition for fixed funding

11/15/2002 Module 4 38

The instructor can review the 4 components directly from the slide.

**Slide 39**

## Interpreting Program

- Develops project specific information
- Calculates rating scores, and following indexes:
  - Prior to 1993:
    - PCR – incl. rutting & structural information
  - Currently:
    - PSC - structural condition, based on cracking (fatigue cracking is main distress)
    - PRC - rutting condition
    - PPC - roughness (IRI)

11/15/2002 Module 4 39

The instructor can read directly from the slide and expand on the information. Basically, the interpreting program develops information that is specific for each project within the network. It then calculates rating scores and several indices. Prior to 1993 a pavement condition rating included rutting and structural information. Currently, a PSC or Pavement Structural Condition index is based on cracking, fatigue cracking it is one of the main distresses. A PRC is a rutting condition index and a PPC is related to roughness.

**Slide 40**

## Project Level Analysis

- In first PMS, project level optimization determined rehab strategy for each project
- Optimizing program ranked output in order of life cycle cost for array of rehabilitation strategies for each project
- Most projects identified early, so many overlays relatively thin
- New software makes project level info easily available to all pavement managers

11/15/2002 Module 4 40

The instructor can explain the details that are outlined on this slide. They can expand on the slide based on the information they learned from the course background document.

**Slide 41**

## Network Level Analysis

- Network analysis was always seen as natural extension of project selection
- Working toward network analysis to optimize project selection within each region for best overall pavement condition over time for fixed funding level
- “What if” scenarios will be run in future

11/15/2002 Module 4 41

In Washington State DOT, network analysis was always seen as a natural extension of project selection. The state is currently working toward network analysis that would optimize project selection within each region of the state to provide overall pavement condition overtime for the fixed funding levels which are available. Although it’s not possible to do so, it is expected that in the future “what if” analyses in scenarios can be run using the data and the models.

**Slide 42**

## WSPMS Performance Equations

Performance equations are developed in three ways:

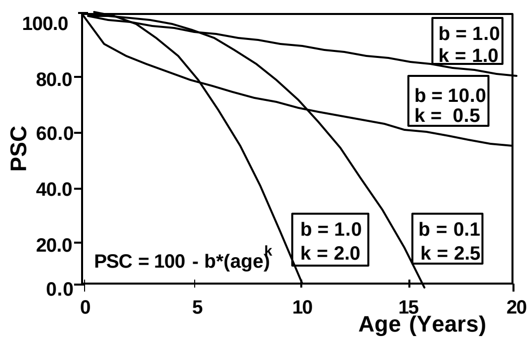
- Regression on data for pavement with known performance during several years
- Default equations covering overall performance of similar pavements in same region
- Equations based on adjustments made using engineering judgement



This slide points out the three different ways that performance equations are developed in Washington DOT. The instructor can read from the slide and expand on the discussion.

**Slide 43**

## Example of Performance Model




Example for relation between structural condition index and age, for various values of regression coefficients b and k. This graph shows examples of four different performance models based on values of b and k coefficients in the model. Where the model is PSC (Pavement Structural Condition) =100 – b (time age) to the k power. This slide merely illustrates the effect of these coefficients. Specifically, it displays the relationship between structural condition index and age. The data itself will be used to determine the values of b and k.

**Slide 44**

## Superior Performing Pavements

- Use of PMS database to locate superior performing pavements
- Evaluate reasons for superior performance of these pavements
- Improve and upgrade performance and design models accordingly



This slide summarizes the use of PM in this example.

**Slide 45**

PMS Data & Performance Models are valuable:

Since 1988 two elements helped convince legislature to increase funding:

1. high quality of PMS data base
2. reliable performance curves showing budget was inadequate to maintain desired performance level

11/15/2002 Module 4 45

The instructor should read from the slide and expand based on his/her knowledge.

**Slide 46**

Module 4 - Objectives

- How is your agency handling performance modeling?
- Do you see possibilities for using these techniques in your state?
- Are your prediction models generic or tailored to your conditions?

11/15/2002 Module 4 46

The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. How is your agency handling performance modeling?
2. Do you see possibilities for using of these techniques in your state?
3. Are your prediction models generic or tailored to your conditions?

# MODULE 5
# 5A – Day One
# 5B – Day Two

# What Can Your Agency Do?

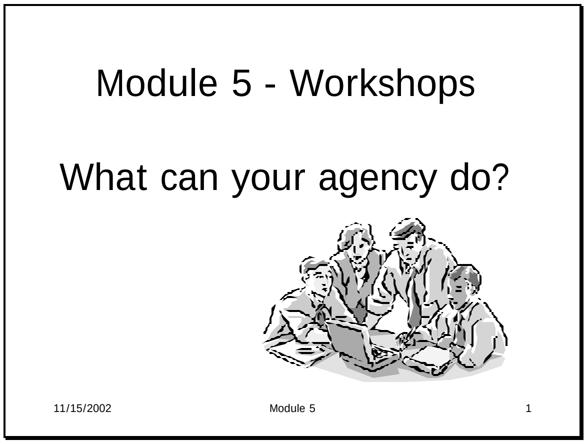
# Module 5
# What Can Your Agency Do?
# Instructional Time: 15 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

1. How can you monitor performance of Superpave using PMS and related data?
2. How should you use maintenance data in a PMS?

**Slide 1**

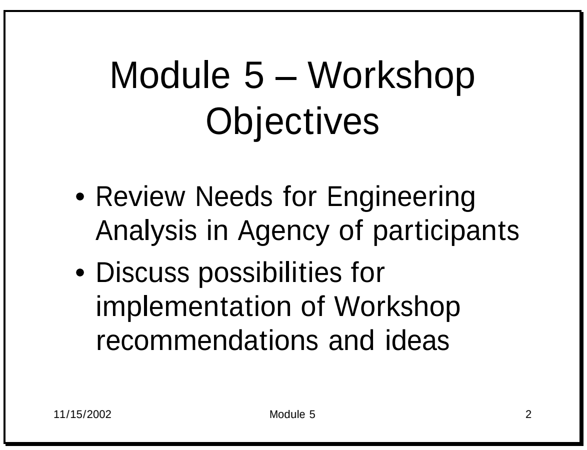



The instructor should at this point, discuss the approach that will be taken in Module 5, the first workshop for the course. The purpose of the workshop is to provide the students an opportunity to interact among themselves and to deal with the aspects of engineering analysis. They should also consider elements within their state DOT that would be amenable to engineering analysis and since SuperPave is such an important topic nationwide, the suggested topic is SuperPave. However, in some cases the agency will have burning topics of their own that are of concern. In those cases, the instructor should not impose the SuperPave topic but should let the groups select their own. It is best to divide the group into sub-units of no more than 10 persons each. For example, if there are 30 students you would have 3 break-out workshops. Equally, the groups should not be less than about 6 persons in size.

<u>Method of dividing the group:</u>

The instructor should consider the make up of the students in selecting the divisions. For example, if there are several states represented in the student body, all members of one state DOT should not be in the same workshop. They should be equally distributed among the other workshops if possible to share information with other state DOTs. If there are 3 maintenance engineers in the group one should go in each sub-group etc. This is intended to stimulate cross agency and cross division interaction and discussion.

**Slide 2**




The objectives of Module 5 are to stimulate the interest of all participants in applying engineering analysis to their agency. It will provide an opportunity for these students to discuss among themselves various applications which could relate to their own needs. The module will involve the students and help them recognize the way they can appropriately apply engineering analysis.

**Slide 3**

## Workshop Procedures (1)

Divide participants into diverse subgroups – maximum 10 persons per subgroup

The group selects:

- A chair person or moderator
- A recorder to make notes
- A scribe to write key points on visual pad
- A reporter (usually separate from chairperson) prepared to report findings for discussion to main group which will reassemble after break out sessions.

11/15/2002 Module 5 3

The instructor should discuss with the groups how they can organize themselves for best results. Generally, the four positions outlined above on the slide have proven to be useful. However, each of these groups is individual and you can only suggest how they organize themselves. They will ultimately do what they feel is best for them and sometimes the members of the groups are not willing to "volunteer" for duties. The instructor should provide guidance rather than forcing the groups to respond. Reporting Back – The instructor should make it clear before the breakout sessions begin that the groups are to be prepared to come back and report their findings by bringing back 1, 2 or 3 newsprint pad sheets and have a reporter give the results. Discussion and interactions should be encouraged during this feedback session.

**Slide 4**

## Workshop Procedures (2)

Timing for Workshops will be flexible, with following approximate schedule:

- 60 min for discussions within Subgroups, incl. preparation of notes and key points on visual pad
- 30 min for class presentations by Subgroups
- 15 min for discussions amongst all participants

11/15/2002 Module 5 4

As the groups begin their work, the instructor should circulate among the groups to observe and answer any procedural questions and should allow the group some start-up time to get going. If after 10 or 15 minutes nothing is really happening, move in and try to provide some direction. Generally, this is not necessary but it may take 5 or 6 minutes to get them started.

**Slide 5**

## Module 5-a What Can Your Agency Do? (Workshop 1)

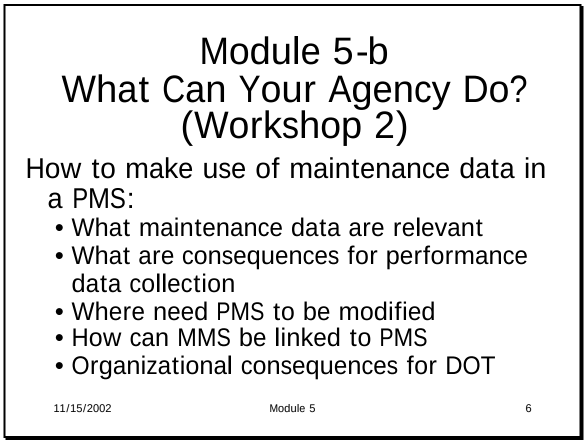
How to monitor performance of Superpave using PMS and related data:

- Database needs: PMS, QC/QA, mix design, pavement design
- How to obtain data from various disciplines
- How to link performance data to other data for each individual location
- Organizational consequences for DOT

11/15/2002 Module 5 5

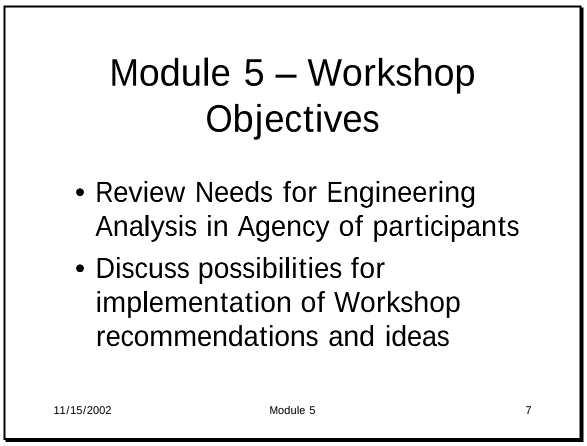
In this workshop, it is suggested that the groups discuss the items listed in the slide and the various aspects of Superpave. In some cases, the group will prefer to tackle a different problem. If they have a strong interest in a different topic, do no try to interfere as long as they are actively interacting.

**Slide 6**




In this workshop, it is suggested that the groups discuss the items listed in the slide and the various aspects of Maintenance. In some cases, the group will prefer to tackle a different problem. If they have a strong interest in a different topic, do no try to interfere as long as they are actively interacting.

**Slide 7**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant’s learning accomplishments.

1. How can you monitor performance of Superpave using PMS and related data?
2. How should you use maintenance data in a PMS?

# MODULE 6

# Pavement (Overlay) Design Evaluation Analysis

# Module 6
# Pavement (Overlay) Design Evaluation Analysis
# Instructional Time: 60 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

1. What overlay design method do you use in your organization?
2. Has it ever been tested and compared with actual observed performance in practice?

**Slide 1**



In Module 6, three examples of engineering analysis related to pavement and overlay design, as well as, evaluation analysis will be presented. These include Washington State DOT, Texas DOT and Arizona DOTs.

**Slide 2**



The objective of Module 6 is to underline the importance of engineering evaluation in design and overlay models. Specifically the module will compare the results of studies in Washington, Texas, and Arizona DOTs and will illustrate the various benefits that have resulted to these three state DOTs based on their own engineering analysis efforts. As a result of this session, participants should be prepared to undertake applications in their own agency.

**Slide 3**



When WSDOT originally set up their pavement management system they did a reasonably good job of predicting network level prioritization for the system being considered. However, the estimates were made based on crude cost estimates. In many cases, the number of pavement sections that could be prioritized was wrong because the funding levels were much lower than predicted or because the costs were higher than expected. Based on experience in the state and the work of the University of Washington combined with the Pavement Management Section an improved approximate design method was developed for overlays called Scoper. This name was developed because the purpose of the method was to “scope out” the cost that would be needed at a higher level than was previously possible. In general, 80% of the designs that are now programmed for final use are reasonably correct because Scoper does a good job. Scoper assesses PMS data and uses it in estimating the overlay thickness and the related costs.

**Slide 4**

## SCOPER Background

- Originally WSPMS applied “standard fix” for pavement rehabilitation based on pre-selected minimum PCR
- Goal: estimate AC overlay thickness
- Use made of Asphalt Institute component analysis method, modified by WSDOT, in OVERDRIVE program

11/15/2002 Module 6 4

The approach taken is to use a technique quite similar to The Asphalt Institute component analysis method. This method was further modified by Ritchie and Mahoney from the University of Washington and used in the computer program OVERDRIVE.

**Slide 5**

## Overlay Scoping Technique

- Total pavement structure developed as new full depth AC design
- Uses pavement type & condition, thickness, subgrade modulus, and traffic
- Judgement required for weighting factors to evaluate existing structural integrity
- Overlay thickness = [required thickness for new design] - [equivalent thickness of existing AC pavement]

11/15/2002 Module 6 5

Uses Asphalt Institutes Method to design full depth pavement structure as if new design with modification to layer coefficients based on Washington characteristics.

**Slide 6**

## Illustration of SCOPER

- Design ESALs = 1,000,000 (assumed)
- Subgrade resilient modulus = 12,500 psi (known or calculated from deflections)
- Full-depth new AC=8.0” (calculated from AI-manual)
- Existing pavement structure
  - 4.2 inches AC (PSC = 60; thus “C” = 0.72)
  - 9.6 inches crushed stone base (coefficient 0.30)
- Convert existing pavement to full-depth AC
  - AC: 4.2” x 0.72 = 3.0”
  - Base: 9.6” x 0.30 = 2.9”
  - Total = 5.9”
- “Scoped” overlay thickness 8.0 - 5.9 = 2.1”

11/15/2002 Module 6 6

The instructor should familiarize himself with the slide and review it with the class. He should familiarize himself with the details from the text before he presents this lecture.

**Slide 7**

## Review of Pavement Design Practices

- Regional engineers design pavements
- Each design reviewed by central office (Service Center)
- WSPMS makes review quick and effective using well maintained PMS data base

11/15/2002 Module 6 7

In Washington State DOT, regional engineers generally design the pavements but each design is submitted for review by the central office at the service center. The PMS section points out that it is possible to make the review quickly and effectively for the regions because of the well maintained database that the state has available.

**Slide 8**

## Design Review Case Study

- Five miles of section of State Road 395
- 1994 condition survey
  - 5 to 15 % low to medium alligator cracking
  - 30 % medium to high longitudinal cracking
- 1994 PSC - 58, projected to 50 in 1995
- Subgrade Soil: Hodgson Silt Loam (ML)
- Base material: 230 - 460 mm silty sandy gravel
- Base Course: 80 mm crushed stone base
- Wearing Course: 100 - 300 mm AC.

11/15/2002 Module 6 8

This slide gives an example of a case study illustrating the Scoper design review process.
The instructor should review the material on the slide with the class, which defines the physical characteristics for the case study.

**Slide 9**

## Case study using three overlay design methods

- 1. SCOPER based on Asphalt Institute Method (Mechanistic-Empirical)
- 2. EVERPAVE, developed by WSDOT (Mechanistic-Empirical)
- 3. DARWin, based on AASHTO's Guide for Design of Pavement Structures (Mechanistic-Empirical)

11/15/2002 Module 6 9

The Washington PMS team, made up of University of Washington personnel and State DOT personnel performed the case study using three (3) overlay methods:

1. SCOPER as outlined,
2. EVERPAVE a mechanistic Empirical design with more details used in WSDOT and
3. DARWIN a typical computer based AASHTO guide.

**Slide 10**

## EVERPAVE Method

- Evaluate effects of subgrade stiffness by back calculating 3 levels (low, medium, high stiffness)
- Account for stress sensitive unbound materials
- Define material properties of each layer, traffic load repetitions and environmental factors
- Compare service lives for fatigue and rutting with projected design ESAL
- Overlay thickness is that which ensures adequate service life for failure criteria (fatigue and rutting)

11/15/2002 Module 6 10

This slide outlines the aspect of the EVERPAVE method and the instructor should cover the five points outlined, pointing out that the EVERPAVE method is more complicated and therefore should be a more correct method than Scoper. However, it also takes a great deal more time and more individual input data.

**Slide 11**

## DARWin Method

- Determine structural number for future traffic $SN_f$ from ESAL's, Initial and terminal serviceability and subgrade modulus (FWD, lab testing, empirical graphs)
- Determine existing structural number $SN_{eff}$ from FWD testing (subgrade and pavement strength) and pavement thickness
- The required overlay structural number $SN_{ol}$ is the difference between $SN_f$ and $SN_{eff}$.
- Overlay thickness is $SN_{ol}$ divided by a coefficient

11/15/2002 Module 6 11

The second method compared was the standard AASHTO method DARWIN that is used in many other states. WSDOT does not typically use DARWIN but they did want to make the comparison to see what the relative results were. The instructor should outline the four points of DARWIN that are presented on the slide and expand the discussion based on the knowledge he's gained from the reading material prepared for this lecture.

**Slide 12**

## Overlay Thickness Comparison

| Core | EVERPAVE | | AASHTO DARWin | | WSPMS SCOPER | |
|---|---|---|---|---|---|---|
| Location | mm | *inch* | mm | *inch* | mm | *inch* |
| 207.85 | 50 | *2.0* | 0 | *0* | 71 | *2.8* |
| 208.00 | 40 | *1.6* | 0 | *0* | 55 | *2.2* |
| 208.50 | 10 | *.4* | 0 | *0* | 56 | *2.2* |
| 209.00 | 95 | *3.8* | 127 | *5.0* | 147 | *5.8* |
| 209.05 | 100 | *4.0* | 132 | *5.2* | 155 | *6.1* |
| 209.40 | 110 | *4.3* | 135 | *5.3* | 143 | *5.6* |
| 209.80 | 35 | *1.6* | 0 | *0* | 65 | *2.6* |
| 210.00 | 60 | *2.4* | 58 | *2.3* | 118 | *4.7* |
| 210.50 | 35 | *1.6* | 0 | *0* | 90 | *3.5* |
| 211.00 | 10 | *.4* | 0 | *0* | 0 | *0* |
| 211.50 | 10 | *.4* | 0 | *0* | 0 | *0* |
| 212.00 | 10 | *.4* | 0 | *0* | 0 | *0* |
| 212.50 | 10 | *.4* | 0 | *0* | 0 | *0* |

11/15/2002 Module 6 12

This slide summarizes information from the case study for various locations within the section. The location is defined where cores were taken. EVERPAVE calculations, DARWIN calculations and SCOPER calculations were carried out using the three independent methods.

**Slide 13**

## Conclusions

- Design of overlays greatly facilitated by availability of well-maintained PMS data base
- Performance data used for all overlay design methods, but for mechanistic design elements extensive use made also of project and structural data
- In WSDOT at present time at 80% of time SCOPER gives right answer

11/15/2002 Module 6 13

This slide presents the conclusions of the case study carried out by WSDOT and the University of Washington. The instructor should read the material and expand on it in closing this section of the module before moving on to the Texas State example.

**Slide 14**

## Texas State DOT's Engineering Analysis Elements

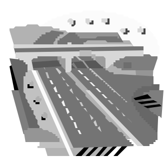
- Module 6:
  - Overview of TxDOT PMIS
  - Analysis of relation between subgrade properties and pavement rutting
- Module 7:
  - Performance of aggregates in concrete pavements
- Module 8:
  - District level index to select preventive maintenance projects

11/15/2002 Module 6 14

The next state PMS we will discuss is the TXDOT work with three (3) engineering examples. As outlined in the slide, we will present an overview of TXDOT PMIS, they call their pavement management system a pavement management information system, PMIS. Following this overview, we will discuss an engineering analysis study in which TXDOT determined the relationship between sub-grade properties and pavement rutting across the very large state. Subsequently, TXDOT examples will be used in Module 7 to discuss performance of aggregates and concrete pavements and in Module 8, a district level index to select preventive maintenance projects.

**Slide 15**

## What is the Texas PMIS



An automated system for storing, retrieving, analyzing, and reporting information to help with pavement-related decision-making processes

11/15/2002 Module 6 15

Texas DOT has PMIS with both network and project level components because Texas is a large, decentralized agency, it lets districts take the lead in finding ways to use PM and current PMIS software. This has the following advantages:

1. Keeping system close to users in field.
2. Easy for central headquarters to identify what parts of PMIS are most useful, and to develop improvements as needed to meet ever-changing district requirements.
3. Ensures that newly developed enhancements to PMIS provide quick benefit, because those enhancements are typically the ones that the districts themselves have requested.
4. Provides for strong engineering related applications to be carried out based on PMIS data, on routine basis by Districts.

**Slide 16**

## Primary Elements and Products of PMIS

- Inventory of pavements in the network
- Database of past and current pavement conditions
- Budget requirements
- Methods for optimizing and prioritizing projects

11/15/2002 Module 6 16

The TXDOT PMIS and has four major elements:

1. Inventory of the pavements in the network.
2. A detailed database is maintained for past and current pavement conditions.
3. Budget requirements are calculated from the available information.
4. Methods for optimizing and prioritizing projects are available in the system.

**Slide 17**

## Pavement Types Surveyed

- Flexible pavement
  - Aggregate base with surface treatment
  - Aggregate base with hot mix A.C.
- Jointed concrete pavement
- Continuously reinforced concrete pavement

11/15/2002 Module 6 17

Trained raters do a visual distress survey each year from September to December on the three major pavement types indicated.

**Slide 18**

## Flexible Pavement Distress

- Rutting
  - shallow & deep
- Patching
- Failures
- Cracking
  - block, alligator, longitudinal, transverse
- Optional:
  - Raveling
  - Flushing

11/15/2002 Module 6 18

PMIS uses separate distress factors in flexible payments from than is rigid payments. As this slide indicates, flexible pavement distresses are rutting both separately for shallow and deep ruts, patching failures, cracking in four categories, block, alligator, longitudinal and transverse. The districts have the option of then recording raveling and flushing depending on any conditions they find present in their own district.

**Slide 19**

## JCP Distress

Distress score from:

- Failed joints and cracks
- Failures
- Slabs with longitudinal cracks
- Shattered slabs
- Concrete patches
- Apparent joint spacing

11/15/2002 Module 6 19

For JCP or jointed concrete pavements, six types of distress are recorded as outlined in the slide (the instructor should read from the slide). These distress ratings combine to make a Distress Score, which ranges from 1 (most distress) to 100(no or very little distress), with score below 80 indicating problems.

**Slide 20**

## CRCP Distress

- Spalled cracks
- Punchouts
- Asphalt patches
- Concrete patches
- Average crack spacing

11/15/2002 Module 6 20

Some people think that all concrete pavements have similar types of distress but it is not true in Texas. Different types of distress are recorded for CRCP or continuously reinforced concrete pavements. Spalled cracks are one of the most important distresses. Punch outs that evolve from several deep spalled cracks are included, as are two types of patches, asphalt patches that are usually temporary and concrete patches and are hoped to be permanent. Finally, cracking itself is recorded in terms of average crack spacing over the length of the section.

**Slide 21**

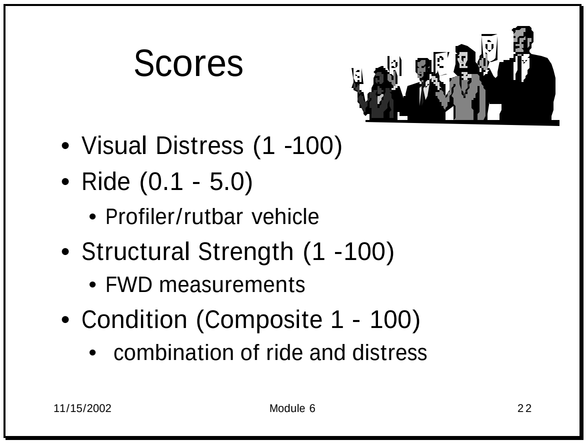
## Distress Score Classes

| DISTRESS SCORE | CLASS | DESCRIPTION |
|---|---|---|
| 90-100 | "A" | Very Good |
| 80-89 | "B" | Good |
| 70-79 | "C" | Fair |
| 60-69 | "D" | Poor |
| 1-59 | "F" | Very Poor |

11/15/2002 Module 6 21

The distress score scheme for PMIS is shown in this slide. One hundred (100) is a perfect score and zero (0) is the worst possible score. You can see we have a "deduct system" as do many states. As discussed previously in pavement management, the most valuable thing is to be able to divide the scale into five categories as shown on the right under description. Very good, good, fair and very poor even though a distress score of 0 to 100 is used. Finally, it is broken down into the five classes ranging from very poor to very good.
Similar scores or indexes are developed for Ride score, Structural Strength index, and Condition score

**Slide 22**

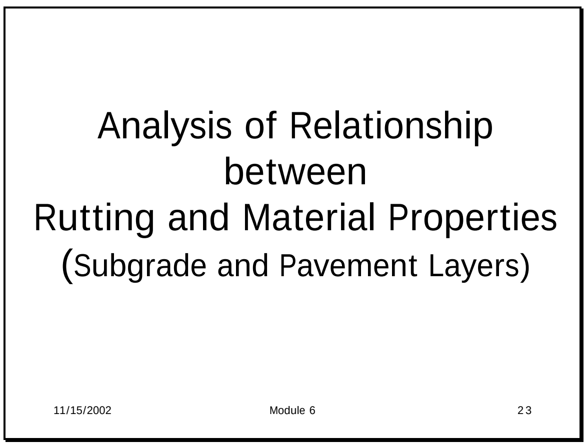



Ride quality, along with automated rut data is collected each year from September to December. Currently, TxDOT uses twelve SIometer/Rutbar vehicles to measure pavement roughness, shallow rutting, and deep rutting. Ride Score is based on user panel rating that ranges from 0.1 (very rough) to 5 (very smooth). The deflection survey is optional and the data can be collected throughout the fiscal year in either network-or project-level format and can be stored in PMIS. TxDOT operates 13 FWDs for collection of deflection data. Structural Strength Index (SSI) reports deflection data. SSI varies from 1 (very weak) to 100 (very strong). An SSI Score below 80 shows that the pavement structure is inferior.

Condition Score uses data from ride and distress surveys. Condition Score ranges from 1 (very poor) to 100 (very good).

Skid resistance can also be used in managing pavements.

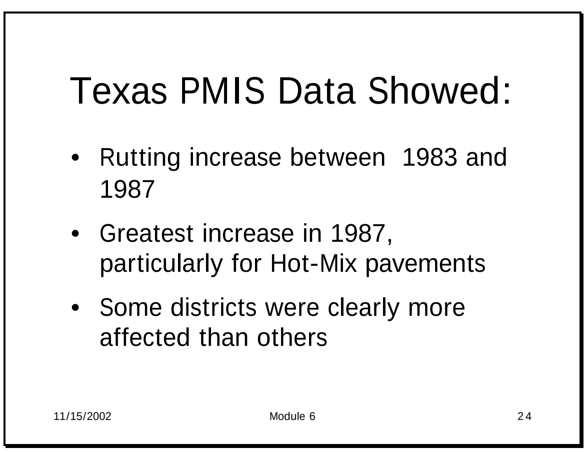
**Slide 23**




In the mid 1980's, Texas experienced excessive rutting in some of their asphalt pavements, they also felt that rutting should be reduced because they were using premium asphalt concrete. Defining this problem, TexDOT turned to their pavement management system. Information extracted from in-house report entitled Analysis of Rutting on Texas Hot-Mix Pavements, printed by the Texas State Department of Highways and Public Transportation, December 16, 1988.

Many flexible pavement sections have rutting of at least ½". Considering that WASHTO had suggested that any pavement with rut depth of ½" or more has reached end of design life, these rutting values represented a sizable problem.

**Slide 24**




In 1987, rutting on hot-mix pavements increased rapidly, not only did frequency of rutting increase, but it was becoming more localized, at times even following exactly along district boundaries.

**Slide 25**

## Major Concerns About Rutting in Hot-Mix Pavements

- Effectiveness of expensive Hot-mix
- Typically used on higher traffic highways, difficult repair scheduling
- Safety risks of deep ruts
- Premature failures present poor image

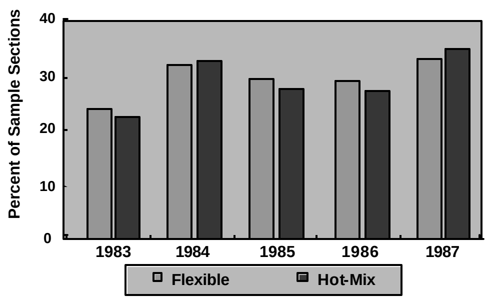
11/15/2002 Module 6 25

Hot-mix pavements are generally thicker than other flexible pavements, representing greater investment of time, labor, material, and money at risk. Because of their enhanced structural properties, hot-mix pavements are typically used for more important high-traffic highway sections so scheduling corrective work is more difficult. Serious rutting causes serious safety risks, particularly during and after heavy rain

Hot-mix pavements are supposed to be carefully designed and constructed. To an average taxpayer, deficiencies (especially premature ones) observed in such a pavement, suggest that the department is not doing its job or does not know how to do its job.

**Slide 26**

## Rutting as % of Sample Sections Flexible Vs. Hot-Mix PMIS Sections



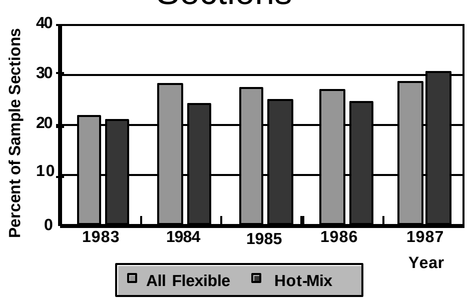

11/15/2002 Module 6 26

This slide depicts the percent of sample sections across the state that display rutting. In this case, the term flexible includes all pavements using asphalts, both surface treatments and hot mix surfaced pavements. In general of course, surface treatments whether single, double or triple are thinner than hot mix pavements. The instructor can discuss the various years showing that hot mix asphalt concrete that should be rut resistant was increasing in rutting, particularly in 1987.

In ‘87 on average 33% of sections showed rutting of at least 0.5”

**Slide 27**

## 1/2”- 1” Rutting as % of Sample Sections

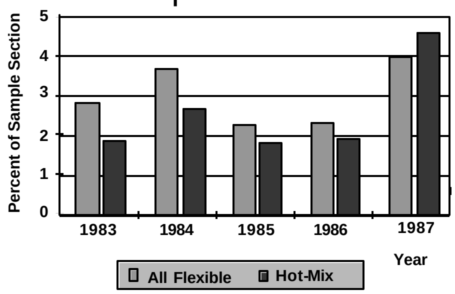



11/15/2002 Module 6 27

Similar patterns were present for rutting in ½ to 1 inch category as shown in this slide. The instructor can discuss the information on the slide. On average 29% of pavement sections showed between ½” and 1” rutting. General trends similar as in previous graph.

**Slide 28**

## More than 1” Rutting as % of Sample Sections




11/15/2002 Module 6 28

This slide depicts the percentage of sections with 1 inch of rutting or more. Typically, about 2 % of sections have exhibited rutting of 1 inch or more. However, in 1987 this jumped to 4 %, which was very disturbing to TXDOT officials. On average 4% of sample sections exhibited 1 inch (or deeper) rutting. General trends are similar but there was a more pronounced decline in ‘85 and ‘86 rut depths.
Larger changes in the 1 inch rut graph are due to expanded vertical scale.

**Slide 29**

## Testing of structural pavement and subgrade properties

- Used FWD data collected for PMIS
- Expressed calculated subgrade strength in resilient subgrade modulus
- Stiffness of base and surface layers related to surface curvature index (SCI)
- Results averaged per county and plotted on maps.
- Measured rutting plotted in similar fashion

11/15/2002 Module 6 29

The instructor should review the 5 items outlined in the slide.

**Slide 30**

## Subgrade Properties

| Category | Subgrade Modulus (psi) |
|---|---|
| Very Poor | 0 - 12,999 |
| Poor | 13,000 -17,999 |
| Fair | 18,000 - 22,999 |
| Good | 23,000 – 27,999 |
| Very Good | 28,000 - 199,999 |
| *State average* | *20,652 for all pavements* |
| *(Fair)* | *20,495 for Hot-mix areas* |

11/15/2002 Module 6 30

This slide depicts subgrade properties in Texas as they are categorized from very poor to very good. It also shows that the state average subgrade is generally in the fair category both for all pavements and hot mix areas.

**Slide 31**

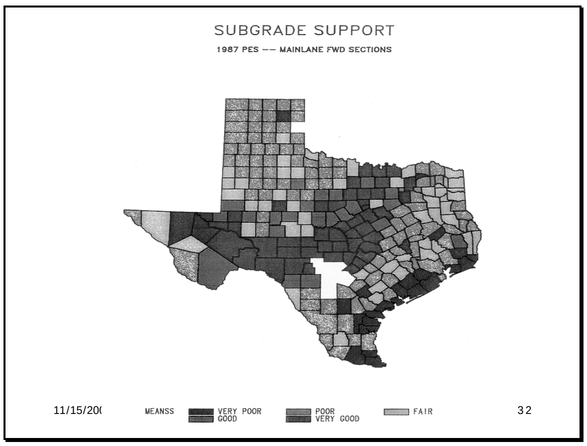
## Pavement Stiffness

| Category | SCI value |
|---|---|
| Very Poor | 25.00 – 99.99 |
| Poor | 19.00 – 24.99 |
| Fair | 13.00 – 18.99 |
| Good | 7.00 – 12.99 |
| Very Good | 0 – 6.99 |
| *State average* | *16.58 for all pavements* |
| | *12.24 for Hot-mix* |

11/15/2002 Module 6 31

TXDOT evaluates pavement stiffness based originally on the unit of the Dynaflect and subsequently on falling weight deflectometer and calculates what they call an SCI “surface curvature index”. This slide shows the value of SCI as it relates to the categories very good to very poor. The averages at the bottom show that hot mix pavements fall on the average in the good category while the average for all pavements is in the fair category.

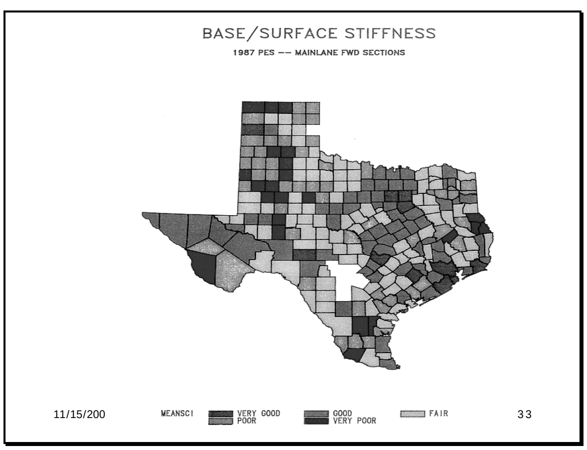
**Slide 32**




The slide shows the distribution of sub grade support values across the state, ranging from very poor to very good. Clearly, the values are related to the geologic features of the state.

Major geological features are readily apparent especially the blue-shaded Balcones Escarpment, Llano Uplift, and Edwards Plateau regions of central Texas. Balcones Escarpment and Edwards Plateau have deep limestones that have very little surface soil. Llano Uplift is primarily limestone with large areas of granite occurring at or near surface.

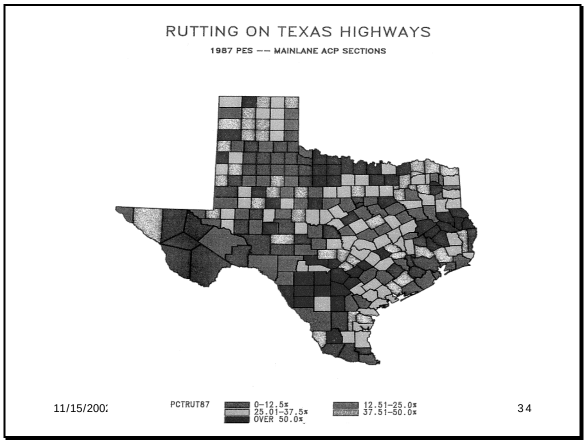
**Slide 33**




This slide depicts the relative distribution and location of base-surface stiffness values across the state. Blue and green sections represent good and very good pavement stiffness. Near the coast these may have a cement treated base.

No clear relationship with subgrade properties.

**Slide 34**




This slide shows the distribution of rutting by county across the state of Texas. Through the pavement management system, the team was able to show that there were relationships among the various characteristics and particularly that there was relationship along district lines. This is due to the fact, that one district uses similar methods throughout that may vary slightly from other districts, because TXDOT is a decentralized agency with lots of authority given to the districts for material selection and construction. Rutting depends on subgrade strength but it also depends on other factors that may vary across the state. These factors were extracted from the PMIS for this study. Rutting values scattered widely across the state with little apparent pattern. Closer examination revealed that certain areas often closely aligned with district boundaries do typically display more rutting than others.

**Slide 35**

## Rutting depends on:

Subgrade strength, but also on:

- Asphalt mix design
- In-place asphalt mix properties
- Amount of traffic loads
- Temperature and traffic speed
- Thickness design

11/15/2002 Module 6 35

This slide shows that rutting was found to depend on 6 factors. The instructor should review the items for the participants.

**Slide 36**

## Conclusions

- Subgrade strength is only one parameter affecting rutting tendency
- No clear pattern between rutting and subgrade properties emerged
- Effects of district boundaries could have been caused by other parameters, such as mix design and quality control
- Demonstrated need for review of mix design and construction techniques

11/15/2002 Module 6 36

The conclusions from this study are demonstrated in this slide and the instructor may read the various conclusions and discuss them briefly in his presentation. The conclusions are of no value unless they produce results or follow up. These are shown in the next slide.

**Slide 37**

## Results of Study

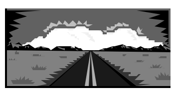
- Changes were made in the hot-mix specifications, and performance based specifications were initiated
- Improved rutting resistance of these new mixes is being tested in practice
- The PMIS database supplied much-needed help for the study.

11/15/2002 Module 6 37

As a result of this study, changes were made in the hot mix specifications used in Texas and performance based specifications were initiated. This continues with a strong emphasis on performance based specifications. Improved rutting resistance of these new mixes has yet to be proven but it is being tested and the pavement management system will provide the data needed to evaluate these tests. It is clear that without the pavement management information system it would not be possible to carry out this study. Currently, a steering committee involving TxDOT personnel, the Asphalt Institute, the Association of General Contractors and the Federal Highway Administration is studying a follow-up on the change in specifications. The instructor should begin to discuss the Arizona study but if time permits, he/she should allow for questions or comments about the work done in Texas.

**Slide 38**

## Overlay Design in Arizona with link to PMS database



Use of SODA as in-house development and implications of possible switch to DARWin.

11/15/2002 Module 6 38

SODA is the acronym name use for the pavement overlay design method used in ADOT. It was developed in house but since AASHTO has developed DARWIN, ADOT wanted to compare the two design methods and hired Texas Research and Development, Incorporated who carried out the study in 1998/1999. SODA has served ADOT well but there is need for update to modern computer environment for the possibility to design pavements with innovative materials, requiring a more mechanistic approach.

**Slide 39**

## Original SODA Development

- SODA (Structural Overlay Design for Arizona) was developed in early eighties
- Deflections measured with Dynaflect
- Deflection data linked to PMS database for traffic and environmental info, and for roughness of pavement prior to overlay.
- Overlay thickness calculated by SODA in DOS environment

11/15/2002 Module 6 39

This slide describes the original development of SODA or structural overlay design method for Arizona. The instructor can cover the four points made on the slide. Prior to SODA, ADOT used empirical relationship developed by California; this uses center deflection under wheels of a Dynaflect. Currently, SODA calculations are done on a mainframe, results of calculations can not be shown on screen.

**Slide 40**

## Original SODA Development
(continued)

- Overlay thickness function of:
  - ESAL's,
  - Regional Factor,
  - SIB (shape of deflection bowl),
  - D5 (Dynaflect deflection furthest from load),
  - Roughness prior to overlay.
- Overlay thickness not dependent on:
  - Deflection under center of load
  - Existing pavement thickness

11/15/2002 Module 6 40

This slide illustrates the equation for thickness design based on multiple regressions on data from 24 sites in Arizona. As part of development, a sensitivity analysis learned that deflection under load center was not statistically significant. Pavement thickness or mechanical properties are not used in the SODA equation but the roughness prior to overlay is used instead.

**Slide 41**

## SODA Modifications

- Dynatest FWD with conversion factors
- Overlay thickness cut off at 6" at high range and 2.5" at low range.
- Small D5 results in over design, large D5 results in under design, in both cases compensation required.
- Thickness equation modified to reflect experience.

11/15/2002 Module 6 41

Dynatest FWD was purchased in the mid 80's and fixed conversion factors were introduced but they produced potential errors. The outcome of SODA calculations is always treated with considerable engineering judgment and the effect of milling is incorporated in the method. For concrete pavements, deflections are also measured but instead of SODA a graph and a table are used to determine the degree of structural damage and the type of rehab to be considered.

**Slide 42**

## DARWin Overlay Design

- DARWin (Design, Analysis,& Rehabilitation for Windows) based on AASHTO Design.
- DARWin can be linked to PMS database
- Overlay design module of DARWin can design 7 types of overlays using 3 different methods.
- Method based on difference between future $SN_f$ and existing $SN_{eff}$

11/15/2002 Module 6 42

As most of you probably already know, DARWIN is an overlay design method, which is a computer based version of the AASHTO design method for overlays. DARWin works with Structural Numbers (SN) for existing pavement (eff), future pavement (f), and overlay (ol). DARWin can be used for 7 overlay design types:

1. AC overlay of AC pavement
2. AC overlay of fractured PCC slab
3. AC overlay of PCC pavement
4. AC overlay of AC/PCC pavement
5. Bonded PCC overlay of PCC pavement
6. Unbonded PCC overlay of PCC or AC/PCC pavement
7. PCC overlay of AC pavement.

**Slide 43**

## DARWin Overlay Design
(continued)

- $SN_{ol} = a_{ol} * D_{ol} = SN_f - SN_{eff}$
  - $a_{ol}$ is structural coeff. for asphalt overlay
  - $D_{ol}$ is required overlay thickness
- $SN_f$ determined from design ESAL's, subgrade modulus (FWD, lab, graphs), initial & terminal serviceability
- $SN_{eff}$ determined from Component Analysis, Remaining Life, or FWD testing:
  - Calculate modulus of all layers & subgrade
  - Assess thickness of pavement layers above subgrade

11/15/2002 Module 6 43

DARWin offers considerable flexibility:
Subgrade modulus can be determined from deflection testing (recommended), from laboratory evaluation, or from graphs. The effective SN of the existing pavement can be determined from deflection testing (recommended), and/or from component analysis (from actual drainage coefficients, layer thickness and structural coefficients), and/or from the remaining life method (based on concept of reducing structural capacity of pavement due to fatigue damage. Actual loadings are compared to design loadings).

**Slide 44**

## Comparison SODA/ DARWin

- Both methods sensitive to ESAL's & regions.
- SODA sensitive to roughness prior to overlay, DARWin is not.
- DARWin sensitive to pavement thickness, initial and terminal serviceability and several other parameters while SODA is not
- DARWin uses all deflection points, SODA only uses shape of deflection bowl and D5
- A smaller D5 increases overlay thickness in SODA, but decreases thickness in DARWin

11/15/2002 Module 6 44

This slide shows a comparison of the two methods, SODA & DARWIN. The instructor can read the material and discuss them. He should familiarize himself with this part of the course by reading the text well in advance of this lecture. The last point, the differing effect of D5 (or D7 for the FWD), makes it impossible to calibrate SODA to DARWin.

**Slide 45**

## DARWin Analyses for historic SODA projects

- 21 DARWin runs, projects from '86 to '98
- In 5 cases DARWin produced similar thickness as SODA (within 1 inch),
- In 7 cases DARWin produced smaller thickness,
- In 9 cases DARWin produced larger thickness

11/15/2002 Module 6 45

To make this study, the project team selected 21 projects carried out from 1986 to 1998. The value of the ADOT pavement management system showed immediately here since it provides the historical data that made it possible to make these comparisons. Design runs were made using both methods and the results of these comparisons are shown above. Five cases, DARWIN and SODA were similar and in seven cases, DARWIN was produced thinner results and in nine cases DARWIN produced thicker results. Results show clearly that there is no relationship or trend.

**Slide 46**

## DARWin Analyses for historic SODA projects (continued)

- Designers adjusted SODA outcome frequently, as it appears mostly in line with DARWin output
- Average overlay thickness found:
  - calculated with SODA 3.5”
  - calculated with DARWin 3.9”
  - actually selected overlays 4.5”

11/15/2002 Module 6 46

In discussions with the design staff from Arizona DOT, they pointed out to us that many of the people in the state felt uncomfortable with the results of SODA because of a few odd results. This suggested that SODA was ineffective. In many cases, the designers used an overlay thickness different than that projected by SODA. This slide shows that the calculated values from SODA averaged 3.5. The averaged calculated with DARWIN was 3.9 but the average of the actual overlays selected based on experience was 4.5. Clearly, the DARWIN method more closely predicts the results that the state pavement design engineers are using.

**Slide 47**

## Conclusions (1)

- DARWin seems good alternative to SODA:
  - Modern computer technology, easy link to PMS databases
  - User friendly, flexible, AASHTO compatible
- On average the overlay thickness for historic projects found with DARWin are between SODA output and actual thickness chosen by pavement designers

11/15/2002 Module 6 47

The conclusions of the study are shown in this slide. The instructor can read the conclusions directly and then discuss them. He should familiarize himself with this study based on the background document for the course.

**Slide 48**

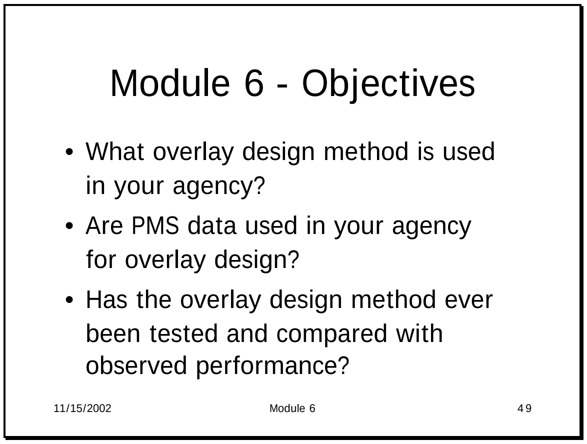
## Conclusions (2)

ADOT’s change to new technology was facilitated by the availability of a good PMS Database

11/15/2002 Module 6 48

Finally, it’s clear from this example that ADOT was able to use its pavement management data to study a problem. Without this data there would not have been clear indication of what was really happening across the state. This same factor we found to be true over and over in all of the state’s considered. A very basic benefit of a pavement management system is that it just provides real knowledge of the past. Rather than trying to depend on someone “remembering” what has happened. This is further exaggerated by the fact that many of the people who have this corporate “memory” have retired or are retiring. This is the end of the presentation on the ADOT overlay study and the instructor should allow time for a discussion.

**Slide 49**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. What overlay design method do you use in your organization?
2. Has it ever been tested and compared with actual observed performance in practice?

# MODULE 7

# Pavement Materials & Construction Performance

# Module 7
# Pavement Materials & Construction Performance
# Instructional Time: 70 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information on slides with graphics, pictures, etc. that are not clear in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

This is the first session on the second day of the course. Take this opportunity to give a quick review of the modules covered in Day 1. Ask the participants if they have any questions and discuss them briefly.

Participant Questions

1. Name any materials or construction techniques used in your agency that we have not discussed?
2. Any new materials?
3. What are they?
4. What are the latest trends in construction in your state?

**Slide 1**

# Module 7: Materials & Construction Performance Evaluation

- Materials and Construction Performance Overview
- Examples of engineering analysis in:
  - Arizona State DOT
  - Texas State DOT
  - Kansas State DOT

11/15/2002 Module 7 1

This slide outlines the contents of Module 7, which includes an overview of materials and their performance, an overview of construction related performance and three examples of engineering analysis, Arizona, Texas and Kansas.

**Slide 2**

## Objectives of Module 7

- Define importance of engineering analysis for materials and construction
- Illustrate and contrast engineering analysis with three practical state examples

11/15/2002 Module 7 2

The objective of Module 7 is to define or re-state the importance of engineering analysis particularly with respect to pavement materials and construction methods. The module will illustrate to the students how engineering analysis has helped state DOT's in Arizona, Texas and Kansas solve important material problems and update their specifications and improve their pavement performance.

**Slide 3**

## Pavement Materials

- Asphalt surface treatments
- Portland cement concrete, with or without reinforcing steel
- Asphalt concrete & other mixes
- Granular base and subbase
- Asphalt, lime, & cement treated base
- Subgrade materials
- Additives (rubber, adhesion agents)

11/15/2002 Module 7 3

This slide outlines a number of the materials that are traditionally used in pavement construction and maintenance. The instructor should review the six types of materials and a variety of additives that are listed in the slide. Based on his/her own experience, the instructor can expand on these materials briefly.

**Slide 4**

## Fundamental Material Characterization

- **Empirical** material characterization
- **Mechanistic** evaluation requires mechanistic testing procedures

11/15/2002 Module 7 4

The instructor can read the information on the slide, which outlines Emperical Evaluation, Emperical Characterization and Mechanistic Evaluation required for mechanistic testing procedures.

**Slide 5**

## Asphalt Hotmix Properties

- Mixture Stiffness
- Resistance to permanent deformation
- Durability
- Fatigue resistance
- Low temperature response
- Permeability

11/15/2002 Module 7 5

The instructor should start by asking the class to name important properties before showing bullet points.
A number of factors are critical to define the properties of hot mix asphalt. This slide lists six of those properties and the instructors should discuss them in detail.

**Slide 6**

## Stabilized Materials

- Cement-stabilized bases are nonlinear elastic
- Asphalt-stabilized bases are nonlinear visco-elastic

11/15/2002 Module 7 6

Two primary stabilized materials are outlined, cement, stabilized basis and asphalt stabilized basis. The cement treated basis is non linear elastic and the asphalt treated is non linear viscal elastic.

**Slide 7**

## Soils and Granular Materials

- Either cohesive or cohesionless
- Properties influenced by:
  - Moisture content
  - Aggregate shape and angularity
  - Grading
  - Stress level

11/15/2002 Module 7 7

This slide summarizes the properties of soils and granular materials as cohesive or cohesion less and then outlines the four factors influencing the properties of soil and granule materials.

**Slide 8**

## Cohesive Soils

- Stress history may have a significant effect on response
- Clay and other cohesive soils are highly nonlinear
- Moisture may have effect on volumetric expansion

11/15/2002 Module 7 8

This slide points out the three relationships that affect cohesive soils. The instructor can deal with these issues by reading directly from the slides and expanding on the material.

**Slide 9**

## Summary for Materials

- As-constructed material properties are important to the performance of pavements
- Material properties should be recorded with the best information available
- Most PMS will limit the detail that can be recorded

11/15/2002 Module 7 9

This slide outlines three major factors relating to materials that have been covered previously. Instructor should review them and summarize the material in his own words, expanding on them based on his /her own experience.

**Slide 10**

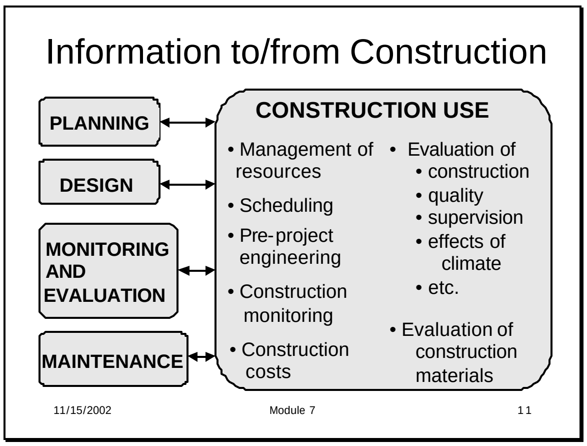
## Construction Overview

- The interrelationships of construction with other phases of PMS
- Construction data documentation for use in PMS Database

11/15/2002 Module 7 10

In this overview, we will treat the inter-relationship of construction with other phases of PMS and refer to the data documentation for construction.

**Slide 11**




This slide outlines the inter-relationships of data flow from planning, design, monitoring, evaluation, and maintenance for construction use. The instructor should review the slide thoroughly before the session and cover the details in his/her presentation.

**Slide 12**

## Construction Documents

- Drawings or project plans with location, dimensions, etc
- Specifications for specific projects
- General “standards and specifications”

11/15/2002 Module 7 12

Construction documents consist of drawings, plans, and specifications and general or standard specifications. The instructors should expand on these based on his/her experience.

**Slide 13**

## Types of Specifications

- Traditional specifications
- Specifications with penalty and bonus clauses
- End product specifications
- Performance based specifications

11/15/2002 Module 7 13

This slide outlines four types of specifications. The instructor should review the written text in the course documents and should discuss these four elements based on the slide and his/her own experience.

**Slide 14**

## Construction Provides Documentation for PMS

- Pavement structure: type, thickness, location
- Materials: properties, variations, quantities
- Costs: total and unit costs
- Construction dates and times
- Environment: weather, drainage problems, etc
- Traffic during construction, traffic measures
- Initial Structural Capacity of pavement
- Initial Roughness of pavement

11/15/2002 Module 7 14

This slide outlines 8 aspects of documentation for construction records that comes from PMS. Discuss them and read from the slide.

**Slide 15**

## PMS Modeling to Compare Treatments and Materials for Arizona DOT

5 Functional Treatments
11 Structural Treatments

11/15/2002 Module 7 15

This section covers 5 functional treatments and 11 structural treatments that were analyzed for the Arizona DOT by Texas Research & Development, Inc.

**Slide 16**

## Functional Treatments

| | |
|---|---|
| SC | Seal Coat |
| FC | Open Graded Asphalt Concrete Friction Course |
| FR | Open Graded Asphalt Concrete Friction Course with Asphalt Rubber |
| RE-FC | Mill + Fill with Asphalt Concrete Friction Course |
| RE-FR | Mill + Fill with Asphalt Concrete Friction Course with Asphalt Rubber |

11/15/2002 Module 7 16

The slide covers 5 functional treatments. The instructor should review those directly from the slide and expand on them based on his/her experience.

**Slide 17**

## Structural Treatments

| | |
|---|---|
| AC | Asphalt Concrete Overlay |
| AC-SC | AC + Seal Coat |
| AC-FC | AC + Asph.Concr.Frict.Course (FC) |
| RC | Recycle in place |
| RC-AC-FC | Recycle in place + AC+ FC |
| RE-AC | Mill + AC |
| RE-AC-FC | Mill + AC + FC |
| RE-AC-FR | Mill + AC + Asph.Rubber FC |
| RE-AR | Mill + AC with rubber |
| RE-RC-FC | Remove + Recycle/replace + FC |
| RE-RC-AC-FC | Remove + Recycle/repl. + AC + FC |

11/15/2002 Module 7 17

This slide outlines 11 structural treatments and the abbreviations that are used in Arizona DOT for the various treatment combinations.

**Slide 18**

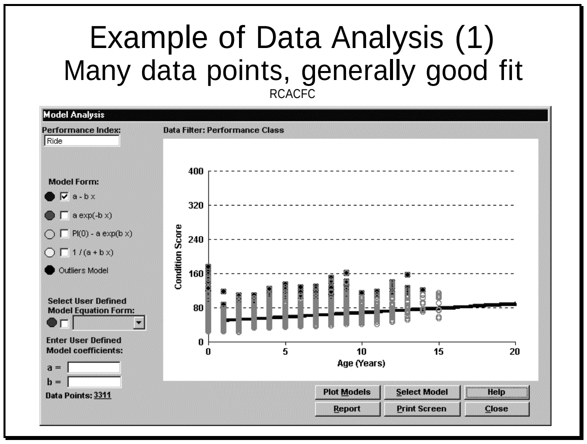
## Organizing the Data

1. Data set developed for 16 treatments for period ‘81-’95. Number of records per treatment varied between 11 and 17187.
2. Data set imported into Visual Modeler for analysis.
3. Performance indicators (PI) Roughness, Friction, Cracking and Rutting were evaluated.
4. Treatments divided over several groups, dependent on relevance for PI

11/15/2002 Module 7 18

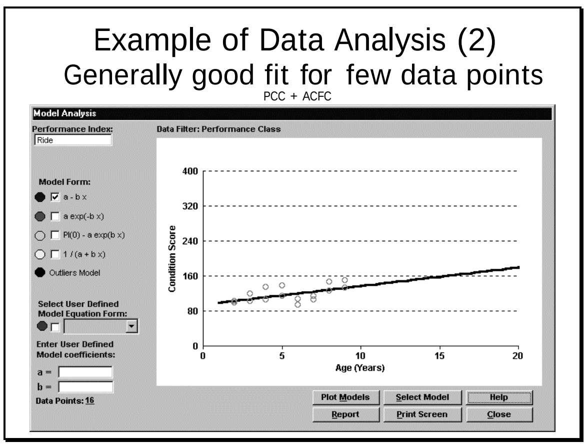
This slide outlines the four steps that were used to organize the data for this analysis. The instructor should read from the slides. The instructor should point out that the slide is not to be read in detail but that trends are to be noted.

**Slide 19**



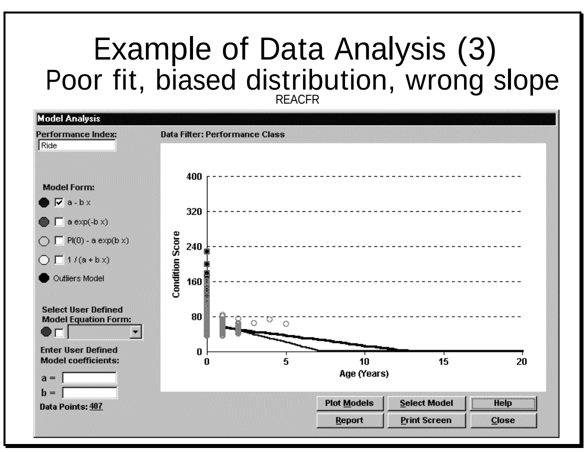

The analysis included comparison of condition score vs. age for various treatments and combinations of treatments. The analysis generally came out in 4 categories. Category 1 was many data points with generally good fit of the analysis, which is the preferred result.

**Slide 20**




For some of the treatments, particularly new types of treatment that don't have many data points but in these cases the data points produced a good fit for the analysis as illustrated here.

**Slide 21**

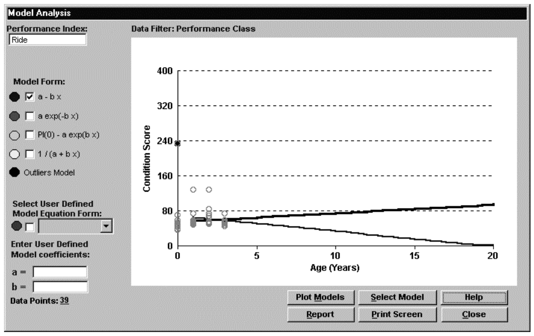



Example of distribution in problem area. Data are heavily biased to early age of 1-2 years with lot of variability. Results produce abnormal slope, although slightly less when outliers at start are omitted. In some cases, there was poor fit to the data because the distribution was biased, thus resulting in a wrong slope. This made it necessary to re-evaluate the data and settle for qualitative results rather than quantitative results in the analysis.

**Slide 22**

## Example of Data Analysis (4)
### Short timeframe, good fit without outlier

REAR




In some cases there was a very short time frame because the technique had only been used for a short period of time. In this case, sometimes there were outliers in the data that indicated a negative slope. In other cases, the outliers could be removed and a good analysis was developed. Such an analysis would always be a pre-cursor to a future analysis that could re-run annually as more data is collected.

**Slide 23**

## Grouping used for Roughness Evaluation

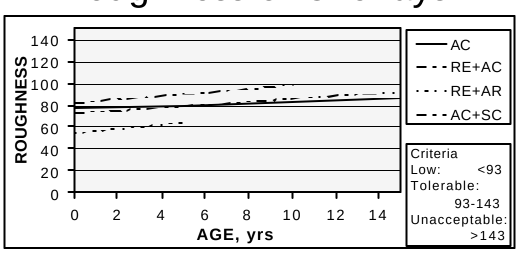
- Structural Overlays, incl. Surf. Treatments
  - AC-REAC-REAR-ACSC
- Structural Overlays + Friction Courses
  - ACFC-REACFC-REACFR
- Functional Overlays
  - FC-SC- FR- REFC-REFR
- Recycling Treatments
  - RC-RCACFC-RERCFC-RERCACFC

11/15/2002 Module 7 23

Groups cover interventions for all pavements combined. For each group up to five mutually comparable interventions have been selected.
Curves from one group is presented here for example.

**Slide 24**

## Roughness of Overlays




| Code | Description | Nr. of Records | Max Age | Significance |
|---|---|---|---|---|
| AC | Asphalt Concrete | 1254 | 15 | High |
| REAC | Layer removal + AC | 539 | 10 | High |
| REAR | Layer removal + Rubber AC | 39 | 5 | Very Low |
| ACSC | AC + Seal Coat | 7205 | 15 | High |

11/15/2002 Module 7 24

This slide illustrates the roughness history of 4 classes of overlays. The data points are not shown since they would obstruficate the results. Therefore, the number of data points used in each of the analysis is shown at the bottom of the slide. In three cases, the results are highly significant and in one case the significance was very low. The instructor should review the text material very carefully before making these presentations.

**Slide 25**

## Grouping used for Cracking Evaluation

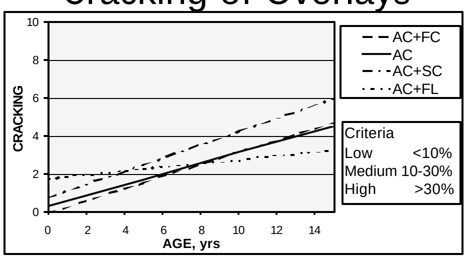
- Structural Overlays with Surface Treatments
  – AC-ACSC-ACFC-ACFL
- Layer Removal & Structural Overlays
  – REAC-REAR-REACFC-REACFR-REACSC
- Recycling Treatments
  – RC-RCACFC-RERCFC-RERCACFC-ROFC
- Functional Treatments
  – SC- FC-REFC-FR-REFR

11/15/2002 Module 7 25

The slide outlines 4 groupings made for analyzing cracking for the various treatments. The instructor can read from that relationship in this slide.

**Slide 26**

## Cracking of Overlays




| Code | Description | Nr of Records | Max Age | Significant |
|---|---|---|---|---|
| AC | Asphalt Concrete | 1237 | 15 | Yes |
| ACFC | Asph. Concr.+ FC | 8364 | 15 | Yes |
| ACSC | Asph. Concr.+ Seal Coat | 7210 | 15 | Yes |
| ACFL | AC + Flush Coat | 756 | 15 | Yes |

11/15/2002 Module 7 26

The analysis of overlays shows strong relationships between cracking and age and the significance of all four overlay types was strong. The number of records is listed but data points are not shown since there are too many to be plotted and still be visible.

**Slide 27**

## Grouping used for Rutting Evaluation

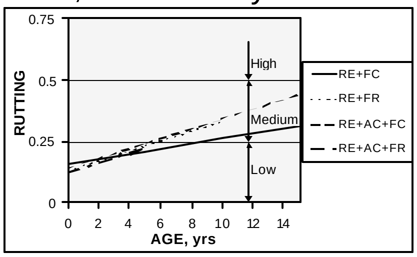
- Structural Overlays including Friction Courses and Rubber
  – AC-ACFC-REAC-REAR
- Layer removal + Friction Courses with/ without Structural Overlays & Rubber
  – REFC-REFR-REACFC-REACFR
- Recycling Treatments
  – RC-RCACFC-RERCFC-RERCACFC

11/15/2002 Module 7 27

This slide outlines the 3 groupings used for rutting analysis. The instructor may read from the slide.

**Slide 28**

## Rutting of Friction Courses after layer removal, incl. Overlays and Rubber




| Code | Description | Nr of Records | Max Age | Significant |
|---|---|---|---|---|
| REFC | Layer removal + FC | 558 | 15 | Yes |
| REFR | Layer removal + Rubber FC | 171 | 10 | Yes |
| REACFC | Layer rem.+AC+ Frict.Course | 2742 | 15 | Yes |
| REACFR | L.removal +AC+ RubberFC | 407 | 5 | No |

11/15/2002 Module 7 28

The instructor can review the slide including the slopes, the number of records etc. as done in previous slides.

**Slide 29**

## Good Performers

| Roughness | Friction | Cracking | Rutting |
|---|---|---|---|
| AC | SC | AC | AC |
| AC-FC | FR | AC-FL | RE-AC |
| FC | RE-AC | FR | RE-FC |
| RE-FC | RE-FR | RE-AR | RE-AC-FR |
| RE-FR | | RE-FC | RE-RC-AC-FC |
| RC-AC-FC | | RE-FR | |
| RE-RC-AC-FC | | RE-AC-SC | |
| | | RE-RC-AC-FC | |

11/15/2002 Module 7 29

This slide outlines the good performers in each of the four analysis that were run for Arizona data. This information was used for determining the types of overlays that should be used in the future by Arizona DOT.

**Slide 30**

## Limitations

- Complete comparison includes cost, construction time and delays, environmental aspects, etc
- Condition prior to overlay (not recorded) can have major influence on performance
- Existing structure (not recorded, except wearing course) has influence on roughness, cracking and rutting.

11/15/2002 Module 7 30

From the slide, the instructor can read the limitations that result from this analysis and how they affect the results.

**Slide 31**

## Conclusions

- Performance modeling is suitable tool to evaluate various rehabilitation treatments for range of performance indicators and various circumstances,
- The success of any engineering analysis depends largely on suitability, completeness and accessibility of PMS databases.

11/15/2002 Module 7 31

The instructor can read from the slide the two basic conclusions that resulted from the Arizona DOT analysis. It should also be pointed out that the beauty of this type of analysis is that each year additional data are added and the analyses may be re-run and they become stronger and stronger as additional data points are added. This ends the ADOT Example.

**Slide 32**

## Use of PMIS Database to Solve PCC Pavements Engineering Problems in Texas

11/15/2002 Module 7 32

**Slide 33**

## University of Texas Study

- Center for Transportation Research (CTR) of UT maintained Rigid Pavement survey database since 1974
- In early 80’s surveys indicated many CRCP pavements showed early signs of distress
- Since no obvious reasons for failure were evident, as first step database was studied

11/15/2002 Module 7 33

The instructor may read from the slide to cover the three points.

**Slide 34**

## Use of CTR/PMIS Database

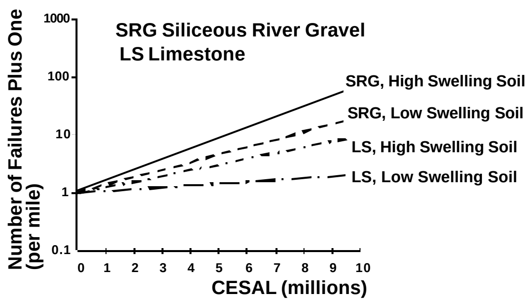
- PMIS database indicated a diversity of performance among CRCP pavements.
- County in which pavement was located correlated well with observed damage.
- Generally particular aggregate type is common within a particular county
- Cause found was type of aggregate used: CRCP with limestone (LS) performed much better than with siliceous river gravel (SRG)

11/15/2002 Module 7 34

The instructor may read from the slide that covers all points of interests.

**Slide 35**

## Example of Distress Curves




This slide points out the relationships of the number of failures per mile for 4 situations. Two types of aggregates siliceous river gravel and limestone and two types of soil conditions, high and low swelling soils. The number 1 was added to the analysis so that the data would never go negative. It is clear that limestone aggregates gave the best performance and limestone aggregates on low swelling soils had very few failures as illustrated in the slide.

**Slide 36**

## Observations from study

Good correlation between computer model, laboratory- and field tests

Significant differences between paired test sections:

- Limestone
  - Fewer cracks
  - Larger crack spacing
  - Smaller crack widths
- Siliceous river gravel
  - Early minor punchouts
  - Seasonal influence on crack width

11/15/2002 Module 7 36

The instructor may read from the slide and should review the text material in the background document before undertaking this lecture.

**Slide 37**

## Summary of Aggregate – Steel – Crack Relationships

| Limestone | Siliceous River Gravel |
|---|---|
| Fewer Cracks | More Cracks |
| Larger Crack Spacing | Smaller Crack Spacing |
| Smaller Crack Width | Larger Crack Width |
| Design Calls for Higher % Steel | Design Calls for Lower % Steel |

11/15/2002 Module 7 37

The instructor can summarize the material on this slide and discuss it with the class.

**Slide 38**

## Findings of Engineering Application

- Additional data and engineering analysis are needed
- PMIS can help in providing data for engineering study

11/15/2002 Module 7 38

This slide points out two findings that the instructor can read directly.

**Slide 39**

## Joint Effort Investigations

- Heat of hydration effects on early-age behavior of CRCP
- Effect of construction season (temperature) on early-age cracking
- Detrimental characteristics of early cracks
- Effect of coarse aggregates on cracking
- Factors affecting crack width
- Determination of setting temperature
- Correlation between field and laboratory cracking
- Simulation of distress in computer program

11/15/2002 Module 7 39

The instructor should carefully review the background document for this section and may read directly from the slide and discuss it with the class.

**Slide 40**

### Kansas State DOT's Engineering Analysis Elements

– Overview of KDOT's PMIS
– Smoothness specifications to maintain construction quality control (with bonus or penalty)

11/15/2002 Module 7 40

The instructor can read directly from the slide. This item will cover an overview of KDOT PMIS and an engineering application related to smoothness specifications.

**Slide 41**

### Overview of KDOT PMIS

- Network Optimization System (NOS) using 3 distress variables to derive optimum list based on linear programming
- Project Optimization System (POS), prediction models currently being revised

11/15/2002 Module 7 41

KDOT's PMIS is made up of two sections: the network level optimization system and a project level optimization system as outlined in this slide.

**Slide 42**

### PMIS Database

| | |
|---|---|
| • Portland Cement Concrete | 700 miles |
| • Composite | 1,100 miles |
| • Full Design Bituminous | 2,800 miles |
| • Partial Design Bituminous | 5,400 miles |
| • TOTAL | 10,000 miles |

Reference system is county/route/milepost

11/15/2002 Module 7 42

This slide outlines the mileage of pavements in the KDOT PMIS database that totals 10,000 miles, which the instructor may read and discuss.

**Slide 43**

## KDOT'S Two Programs

- Large projects, often selected on "worst first" basis, including formula for traffic, age , funding, etc
  - 100 - 200 miles per year reviewed by peer group as part of project selection
- Rehabilitation of 1,200 miles per year using state funding (NOS)
  - 1,000 miles FWD testing per year



This slide outlines the programs KDOT uses to program their pavement preservation data using their PMIS. The instructor should use their background document and discuss this slide with the class.

**Slide 44**

## NOS Requires Roughness, Rutting & Transverse Cracking Information

Examples of Severity Levels

| Levels | Roughness | Rut Depth |
|---|---|---|
| 1 | <1.66 m/km | <13 mm (1/2") |
| 2 | 1.66 to 2.59 m/km | 13 to 25 mm (1/2 to 1") |
| 3 | >2.59 m/km | >25 mm (1") |

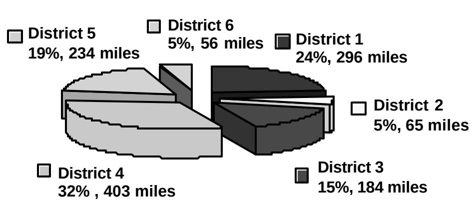


This slide gives the severity levels for roughness and rut depth as an example which are used in PMIS. The instructor should review the background document and review these slides with the class.

**Slide 45**

## Distribution of Rutting by District

1989




Length of Level 2 and 3 Rutting (>13 mm) with total of 1238 miles
Length of total Network 10,000 miles



This is just one example of a report that can be generated by the KDOT PMS. The miles in each district refer to the length per district of pavements with more than 13 mm (1/2") rutting, their total length for the entire network is 1238 miles. The percentages refer to the amount of rutted pavements in each district. It can be seen that the rutting problem varies substantially between districts.

**Slide 46**

## Project Level Optimization System (POS)

- Projects selected by districts - reviewed by design team at state level considering distress etc, but no formal decision program
- POS currently being revised

11/15/2002 Module 7 46

This slide discusses how the project level system operates and the instructor should review the background document and discuss the slide with the class.

**Slide 47**

## Developing Performance Models

- Data is collected on three randomly selected 30 m (100’) subsections per mile
- Results in almost no repetitive data, lack of year-to-year continuity and consequently difficulty in upgrading performance models
- Points out need for research element in PMS

11/15/2002 Module 7 47

This slides points out three aspects of developing performance models. The instructors should review the background document and discuss these points with the class.

**Slide 48**

## As-Constructed Smoothness Specifications

- Kansas changed their roughness specification to include initial smoothness control
- PMIS has verified pavements
  - are now smoother
  - now have longer lives

11/15/2002 Module 7 48

The instructor should discuss this slide with the class after reviewing the background document.

**Slide 49**



The instructor should discuss these 4 points based on his knowledge and review of the background documents.

**Slide 50**



The instructor should review the background document prior to giving this lecture and then should discuss the 3 points outlined on this slide.

**Slide 51**



The instructor should review the background document and discuss the 6 points on the slide with the class.

**Slide 52**

## Schedule for Adjusted Payment for AC, Similar to PCC,

with 5mm (0.2”) Blanking Band

| Profile Index (PRI) (mm / km per 0.16 lane km) | Contract Price Agreement per 0.16 lane km (Dollars) |
|---|---|
| **32 or less** | **+152.00** |
| **32.1 to 47** | **+76.00** |
| **47.1 to 142** | **0.00** |
| **142.1 to 174** | **-102.00** |
| **174.1 to 205** | **-203.00** |
| **205.1 to 237** | **-254.00** |
| **237.1 or greater** | **-305.00** |

11/15/2002 Module 7 52

The instructor should review the background documents and review the items on this slide with the class.

**Slide 53**

## Effects of 1990 Profilograph Results for 2 Blanking Bands

PRI = Profile Index

| **No. of .16 km sections** | **Compliance with specified PRI (mm/km) for 0.2” and 0.01” Blanking** | | | | | |
|---|---|---|---|---|---|---|
| ***5mm (0.2”) blanking*** | PRI 0-47 Bonus | (%) | PRI 47-142 Full Pay | (%) | PRI >142 Penalty | (%) |
| 851 | 547 | 64 | 226 | 27 | 78 | 9 |
| ***.25 mm (0.01”) blanking*** | PRI 0-158 Bonus | (%) | PRI 158-631 Full Pay | (%) | PRI >631 Penalty | (%) |
| 842 | 71 | 8 | 753 | 90 | 18 | 2 |

11/15/2002 Module 7 53

This slide compares the results obtained from reading the profilograph data using two separate blanking bands. The background text completely covers these items and the instructor should review them before making this lecture.

**Slide 54**

## Adjusted Payments for AC Pavements (1991)

| Profile Index (PRI) **(mm per km / 0.16 lane km)** | Contract Price Agreement **per 0.16 lane km (Dollars)** |
|---|---|
| **110 or less** | **+152.00** |
| **110.1 to 158** | **+76.00** |
| **158.1 to 473** | **0.00** |
| **473.1 to 631** | **0.00 (correct back to 394 mm/km or less)** |
| **631.1 to more** | **-203.00 (correct back to 394 mm/km or less)** |

11/15/2002 Module 7 54

This slide summarizes the contracted price agreement that was used in contracts in 1991 based on the available profilograph index.

**Slide 55**

## Profilograph results with 1993 Zero .25 mm (0.01") Blanking Band

| Roadway | No of 0.16 kilometer sections | Compliance with specified PRI (mm/km) | | | | | |
|---|---|---|---|---|---|---|---|
| | | PRI (0-158) Bonus | (%) | PRI (158.1-631) Full-pay | (%) | PRI (>631) Penalty | (%) |
| 1990 (reanalysis) | 842 | 71 | 8 | 753 | 90 | 18 | 2 |
| 1991 (reanalysis) | 1890 | 57 | 3 | 1796 | 95 | 37 | 2 |
| 1992 | 5866 | 1467 | 25 | 4341 | 74 | 58 | 1 |
| 1993 | 4568 | 625 | 15 | 3499 | 84 | 42 | 1 |



This slide summarizes the data for 1990 to 1993 with a re-analysis of the 90 & 91 data based on the zero blanking band. The background document covers these details carefully and the instructor should review them before making this lecture.

**Slide 56**

## Results of Cost Analysis of AC Pavement Smoothness Specifications

| Year | No. Of 0.16 km Sections | Bonus ($) | Bonus/ Lane km Paved ($/km) | Penalty ($) | Penalty Lane km Paved ($/km) |
|---|---|---|---|---|---|
| 1991 | 1890 | 4256 | 14.07 | 7919 | 26.19 |
| 1992 | 5866 | 191084 | 203.59 | 4060 | 13.43 |
| 1993 | 4568 | 94488 | 129.25 | 3857 | 12.75 |



This slide points out the number of sections involved in bonus and penalty payments and summarizes the amount of bonus and penalty paid. It points out that bonuses peaked in 1992 and this is what caused the concern and resulted in the adjustments made in 1993 that produced decreased bonuses and kept penalties at about the same level.

**Slide 57**

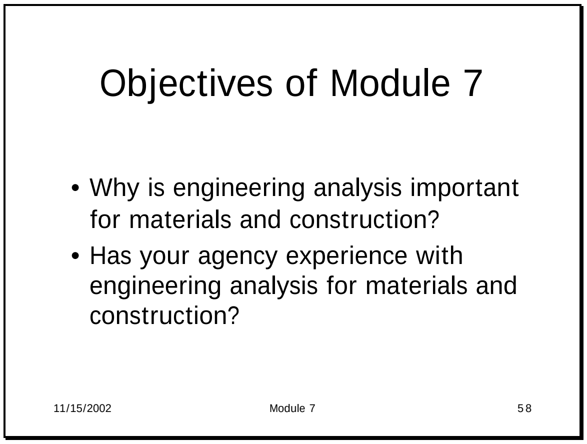
## Conclusions

- Availability of distress and other data in PMIS database essential for study
- Smoothness specifications evolved over several years
- Implementation of zero blanking band resulted in better pavements
- Incentive payments encouraged better paving



This slide summarizes the conclusions of the Kansas DOT study on pavement smoothness. The instructor should review these conclusions with the class.

**Slide 58**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. Name any materials or construction techniques used in your agency that we have not discussed?
2. Any new materials?
3. What are they?
4. What are the latest trends in construction in your state?

# MODULE 8

# PMS for Tracking Preventive Maintenance Actions

# Module 8

# PMS for Tracking Preventive Maintenance Actions

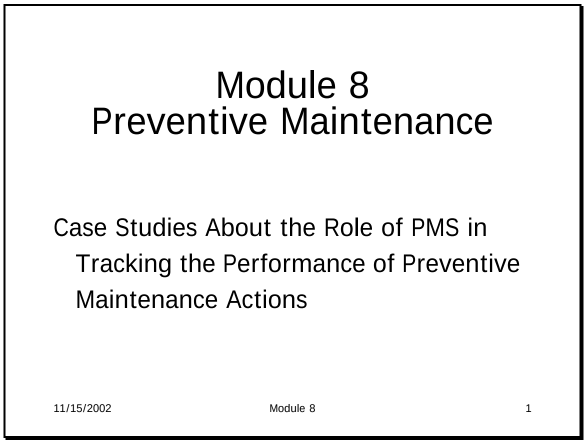
# Instructional Time: 40 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

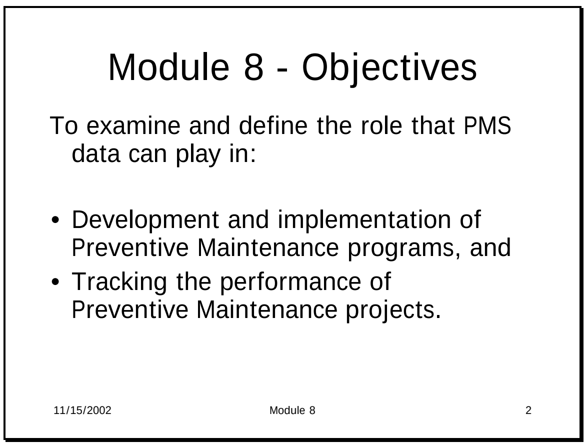
1. Is your agency using PMS to track the performance of preventive maintenance?
2. How are you doing that?
3. Does your organization have a separate budget for preventive maintenance?
4. Does your agency make a clear distinction between preventive maintenance and preservation?

**Slide 1**



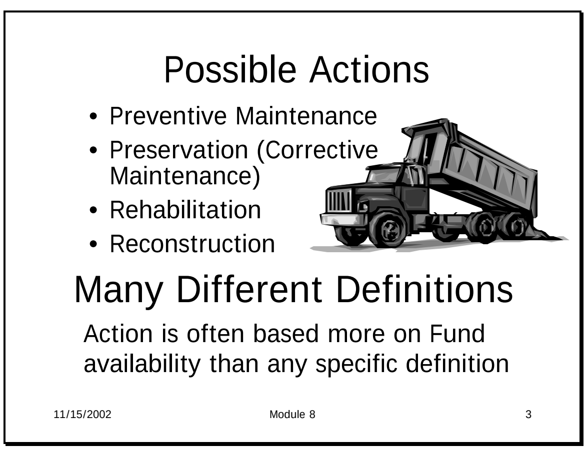

This module covers preventive maintenance. Several case studies are presented about the role of the PMS system in tracking the performance of preventive maintenance actions in various DOTs.

**Slide 2**




The objective of Module 8 is to clearly define for the participants the relationship of preventive maintenance, reactive maintenance and rehabilitation. It will help the students to comprehend how preventive maintenance fits into the pavement management concepts of their own DOT and it will stimulate their interest in applying preventive maintenance techniques where appropriate.

**Slide 3**




Once a pavement is constructed and begins to serve the traveling public, there is generally four classes of actions that can be taken by the agency once the pavement begins to deteriorate.

1. Preventive maintenance,
2. Preservation, that is corrective maintenance, Rehabilitation, and
3. Reconstruction.

There are many different definitions of these various activities and one of the reasons there is so much confusion is that the definition often depends on some funds. State agencies are very adept at learning how to best utilize money that has been set aside in dedicated pools and if the agency feels that a particular stretch of road needs action it does not hesitate to use money in one or another of its funding categories regardless of the type of work they intend to undertake. This has created some misunderstandings about the definitions of these various actions. In this module, we will try deal with the four actions listed above. Irrespective of the source of funding.

**Slide 4**

## AASHTO's Definition of Preventive Maintenance

The <u>planned strategy</u> to apply cost effective treatments to an existing roadway system and its appurtenances to preserve the system, retard future deterioration, and maintain or improve the functional condition of the system.

-*AASHTO's Standing Committee on Highways*

11/15/2002 Module 8 4

The instructor can review AASHTO's definition of preventive maintenance that is listed on the slide and should serve as the proper definition for this course.

**Slide 5**

## Preventive versus Corrective Maintenance

- Preventive Maintenance actions should be taken before noticeable deterioration to increase life
- Preservation (Corrective) Maintenance is taken after deterioration to correct damage and thus increase life

11/15/2002 Module 8 5

This slide summarizes the relationship between preventive and corrective maintenance and the instructor may summarize the information given in the slide and expand on that information using his/her own experience.

**Slide 6**

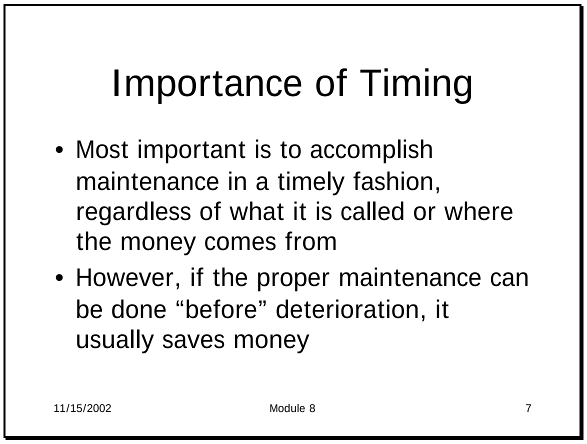
## Examples of Preventive Maintenance Treatments (AASHTO)

- **AC Pavements**
  - Thin overlay
  - Mill and overlay
  - Chip seal
  - Microsurfacing
  - Crack treatment
  - Shoulder seals
  - Ultrathin Overlay
- **PCC Pavements**
  - Joint resealing
  - Spall repair
  - Crack sealing
  - Diamond grinding
  - Shoulder seals
  - Drain cleanout
  - Dowel retrofit
  - CPR

11/15/2002 Module 8 6

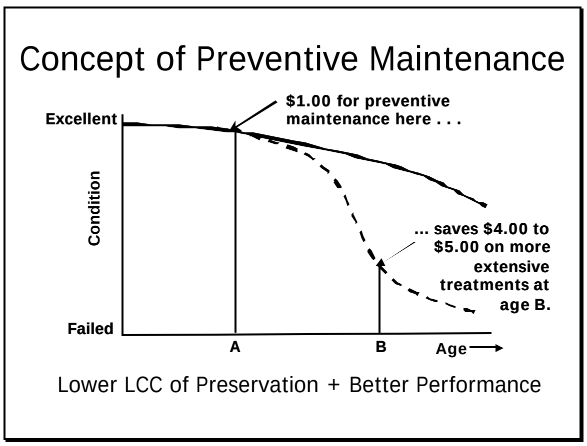
The instructor may summarize the various classes of activities that are listed by AASHTO as preventive maintenance treatments. One column is for asphalt concrete pavements and the second column is for Portland cement concrete pavements.

**Slide 7**



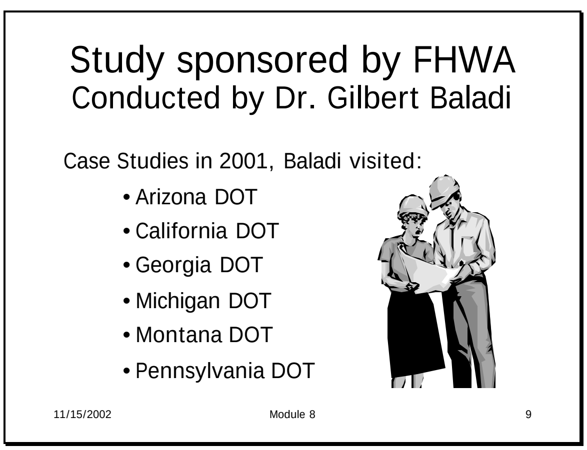

Timing is of particular importance in preventive maintenance. This slide outlines two major points related to timing and the instructor should cover those with the class and expand on the details based on his/her experience.

**Slide 8**




AASHTO's concept of preventive maintenance is illustrated in this slide. If a dollar is spent for preventive maintenance at time "A" illustrated on the slide it generally will save up to $4 or $5 dollars of more expensive corrective maintenance spent at time "B".

**Slide 9**




The first section of this module is a study conducted by Dr. Baladi for FHWA in 2002. Dr. Baladi visited the six states outlined in the slide and observed the relation between their pavement management system and preventive maintenance.

**Slide 10**

## Additional Studies

Case Studies in:

- Texas DOT:
  - District Level Index to Select TxDOT Projects for Preventive Maintenance
- Wisconsin DOT:
  - Preventive Maintenance Strategies for Continuously Reinforced Concrete Pavements

11/15/2002 Module 8 10

In addition to the Baladi study, case studies will also be presented from Texas DOT and Wisconsin DOT.

**Slide 11**

## Scope of Baladi Study
### 6 States

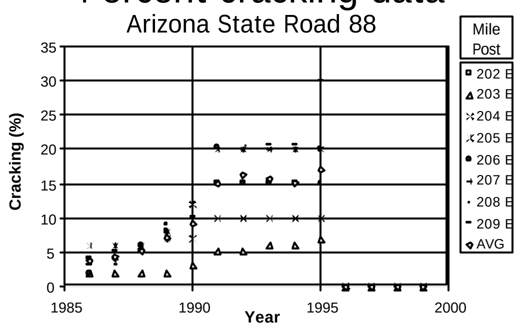
- To evaluate the state-of-the-practice of DOTs who developed and implemented a Preventive Maintenance (PM) program based on pavement needs.
- To investigate and analyze distress data used to select PM project boundaries, time for construction, and PM actions by the DOTs.

11/15/2002 Module 8 11

This slide presents the scope of the Baladi study that involves two major points outlined above. The instructor should cover the materials on the slide.

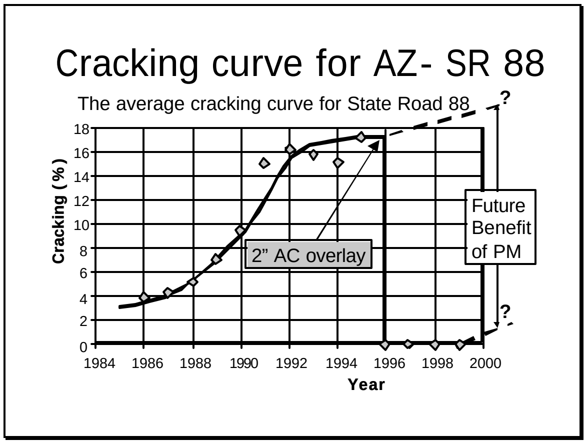
**Slide 12**

## Percent cracking data
Arizona State Road 88



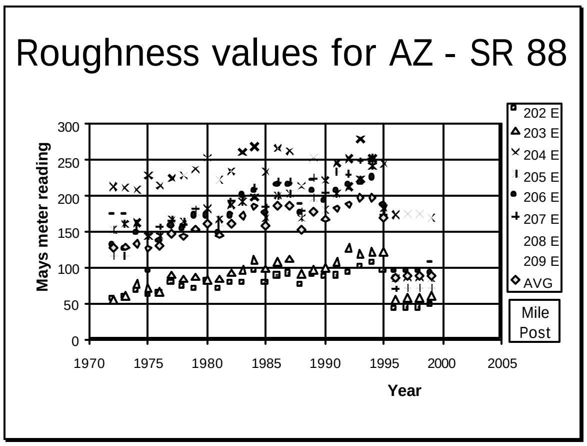

This slide and the following three slides depict the historical distress data of SR 88 between mileposts 201 and 209. This slide shows the percent cracking of each mile and the period (1986 to 1999).

**Slide 13**



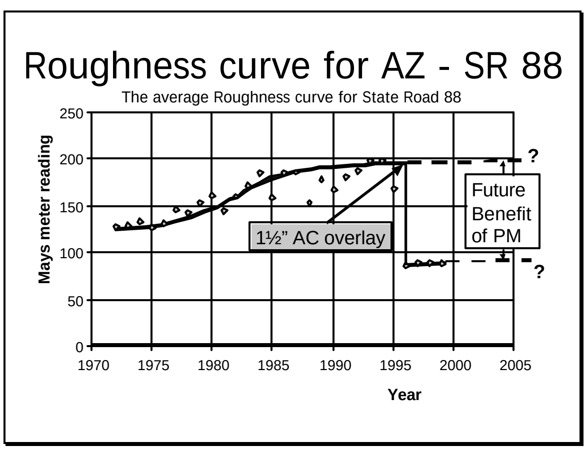

This slide shows the average percent cracking of SR 88 for the same period. As can be seen, the percent cracking increased from about 3% in 1985 to about 17% in 1995 and it decreased to 0 after the preventive maintenance action was completed in 1996. Four years after construction, the percent cracking remained at 0% level.

**Slide 14**




This figure shows the actual roughness values between mile post 201 and 209.

**Slide 15**




This slide shows the averages for roughness from 1972 through 1999. The maintenance activity reduced average roughness from 200 to 80. The slide depicts this as the benefit of maintenance.

**Slide 16**

## Preventive maintenance actions on State Road 16 in California

| Section number | Preventive maintenance action | Age (years) | Pavement condition |
|---|---|---|---|
| 1 | ½-in rubberized AC overlay | 7 | Very good |
| 2 | ¾-in rubberized AC overlay | 7 | Very good |
| 3 | 1-in rubberized AC overlay | 7 | Excellent |
| 8 | ½-in rubberized AC overlay | 7 | Very good |
| 9 | ¾-in rubberized AC overlay | 7 | Very good |
| 12 | 1-in rubberized AC overlay | 7 | Excellent |
| Control | 4-in AC surface | 7 | Patching in wheel paths due to alligator cracking |
| East of 15 | 1-in conventional AC overlay | 2 | Longitudinal and transverse cracks |

In 1995 to 1996, Caltrans undertook a variety of preventive maintenance actions on State Road 16. This slide summarizes those preventive maintenance actions involving rubberized asphalt concrete overlay and a standard asphalt concrete overlay. It can be seen that all of the rubberized treatments are performing better than the standard treatments after 7 years.

**Slide 17**

## Georgia DOT PM Actions for Rigid Pavements

- Slab replacement
- Under sealing
- Full-depth repair
- Partial-depth repair
- Joint resealing
- Diamond grinding to correct faulting and ride quality



Georgia DOT has used a wide variety of rigid pavement preventive maintenance actions and this slide outlines 6 such actions for rigid pavements.

**Slide 18**

## Georgia DOT PM Actions for Flexible Pavements

- Microsurfacing
- 1.5-inch overlay
- Milling, Interstates: 3" mill and 4.5" fill
  State roads: Fill can be less than mill
- Crack sealing
- Slurry seal
- Surface treatment
- Patching
- Chip seal
- Chip seal interlayer and HMS overlay
- Shoulder paving



This slide outlines 10 types of preventive maintenance actions that Georgia DOT uses for flexible pavements. The instructor may summarize them directly from the slide.

**Slide 19**

## Georgia DOT Preventive Maintenance Strategies

1. Optimum timing of Actions
2. Adequate Preventive Maintenance Budget
3. Fast Track Response
4. Strict Specifications

11/15/2002 Module 8 19

This slide outlines 4 factors that relate to Georgia DOT preventive maintenance strategies. The instructor may discuss them directly from the slide.

**Slide 20**

## Expenditures of Preventive Maintenance Program in Michigan

| Year | Annual Budget (Million $) |
|---|---|
| 1992 | 6 |
| 1994 | 16 |
| 1996 | 24 |
| 1998 | 54 |
| 2000 | 60 |

11/15/2002 Module 8 20

It should be noted that the total expenditures of the MDOT preventive maintenance program have increased over time from $6,000,000 in 1992 to $60,000,000 in 2000 as shown in this slide. The increases were justified based on the benefits and the successes of the preventive maintenance program.

**Slide 21**

## Michigan DOT PM Actions for Flexible & Composite Pavements

- Non-structural bituminous overlay
- Surface milling & non-structural
- bituminous overlay
- Chip seals
- Micro-surfacing
- Crack treatment
- Over-band crack filling
- Bituminous shoulder seal
- Ultra thin overlays

11/15/2002 Module 8 21

This slide summarizes 8 types of preventive maintenance actions that Michigan DOT carries out for flexible and composite pavements. The instructor can review them directly from the slide for the class.

**Slide 22**

## Michigan DOT PM Actions for Rigid Pavements

- Full depth concrete pavement repair
- Concrete joint resealing
- Concrete spall repair
- Concrete crack sealing
- Diamond grinding
- Dowel bar retrofit
- Concrete pavement restoration
- Bituminous shoulder seal
- Open-graded underdrain cleaning/repair

11/15/2002 Module 8 22

This slide outlines 9 actions that Michigan DOT carries out for preventive maintenance of rigid pavements. The instructor can review them directly from the slide.

**Slide 23**

## MDOT selection of PM treatment based on condition/benefits (1)

Flexible and Composite Pavements

| TREATMENT | RSL years | Distress Index | RQI | Rut Depth (mm) | Life Extension years |
|---|---|---|---|---|---|
| Non-struct.bitum.overlay | 3 | <40 | <70 | <12 | 5 to 10 |
| Surf.mill+non-st.bit.overl | 3 | <40 | <80 | <25 | 5 to 10 |
| Double chip seal | 5 | <30 | <54 | <3 | 4 to 7 |
| Single chip seal | 6 | <25 | <54 | <3 | 4 to 7 |
| Micro-surfacing/multiple | 5 | <30 | <54 | <25 | 4 to 6 |
| Micro-surfacing/ single | 10 | <15 | <54 | <25 | 3 to 5 |
| Crack treatment | 10 | <15 | <54 | <3 | Up to 3 |
| Crack filling | 7 | <20 | <54 | <3 | Up to 2 |
| Ultra-thin bitumin.overlay | 7 | <20 | <54 | <3 | no data |

This table shows the states selection of treatment based on various levels of condition and the coverage life extension observed in the PMS in Michigan.

**Slide 24**

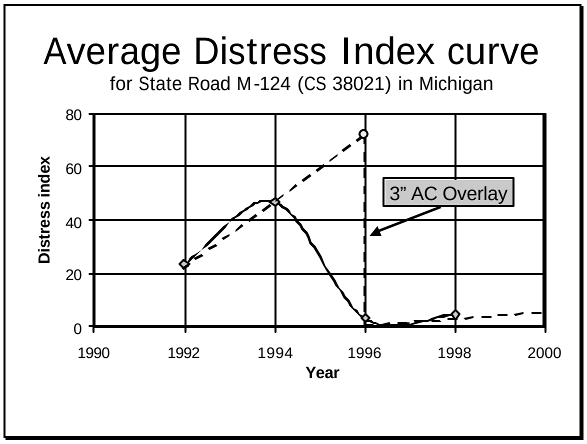
## MDOT selection of PM treatment based on condition/benefits (2)

Rigid Pavements

| TREATMENT | RSL years | Distress Index | RQI | Life Extension years |
|---|---|---|---|---|
| Full depth concrete pavement repair | 7 | <20 | <54 | 3 to 10 |
| Concrete joint resealing | 10 | <15 | <54 | 3 to 5 |
| Concrete spall repair | 10 | <15 | <54 | Up to 5 |
| Concrete crack sealing | 10 | <15 | <54 | Up to 3 |
| Diamond grinding | 12 | <10 | <54 | 3 to 5 |
| Dowel bar retrofit | 10 | <15 | <54 | 2 to 3 |
| Concrete pavement restoration | 3 | <40 | <80 | 7 to 15 |

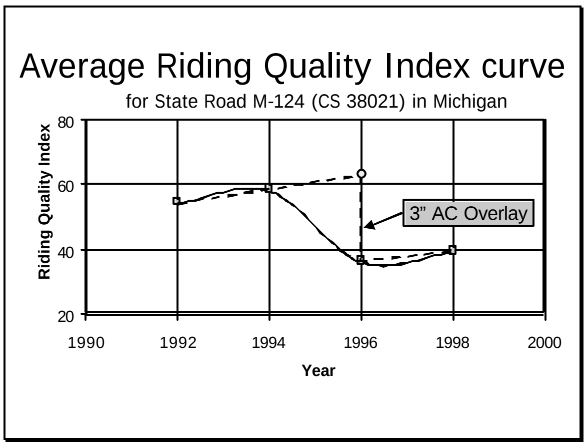
This extension shows similar information for Rigid Pavements.

**Slide 25**




This slide shows the average distress data from Michigan State Road M-124. The circle point depicts the expected distress in 1996 without Preventive Maintenance.

**Slide 26**




This slide shows a similar plot for Riding Quality. The circle shows projected ride quality in 1996 without maintenance. Probable reduction was 28 points.

**Slide 27**

## Penn DOT Preventive Maintenance Actions for Interstate 78

- Mill the existing asphalt concrete
- Test all joints load transfer using FWD
- Repair deteriorated joints using full depth concrete patches
- Place asphalt concrete overlay
- Saw cut asphalt concrete to match PCC joints
- Seal saw cuts in the asphalt

Example of Difficulty in Defining Preventive Maintenance

11/15/2002 Module 8 27

The instructor should review the slide, which is self evident.

**Slide 28**

## Findings of Baladi Study

- This study shows potential value of Preventive Maintenance
- The study does not show follow-up data, however, the PMS provides a data base for storing relevant data
- The follow-up data could show actual benefits of Preventive Maintenance

11/15/2002 Module 8 28

The instructor should summarize the three points outlined in the slide.

**Slide 29**

## Results of Baladi Study

- The Baladi study shows "before and after" data. (Not really yet the proof we need).
- Continued observations and recording in the PMS data base can show the quantitative value of Preventive Maintenance. (Most DOT's don't have the data yet).

11/15/2002 Module 8 29

The instructor can directly review the 2 points written on the slide that show the data is so far incomplete.

**Slide 30**

## District Level Index to Select TxDOT Projects for Preventive Maintenance

11/15/2002 Module 8 30

Texas is divided into 26 districts and each district has its own preventive maintenance budget and considerable autonomy in applying that budget.  This module describes how the Fort Worth district has used the pavement management information available to allocate preventive maintenance budgets effective.

**Slide 31**

## Fort Worth District

- 8100 Lane Miles , divided over 8 counties
- Annual $7,000,000 Program
- Uses PMIS in combination with local area engineer's recommendations to select projects
- Needed new tool to select most critical projects for funding: District Level Index

11/15/2002 Module 8 31

As indicated in the visual, the Fort Worth district covers 8 counties including 8100 lane miles. They distribute an annual budget of 7 million dollars in their preventive maintenance program. The Texas PMS is called PMIS the Pavement Management Information System and the data from the PMIS is used in combination with the recommendation from the individual county area engineers to select projects for funding. In 1998, the district pavement engineer recognized the need for a new tool to provide better information on the most critical projects that needed funding.

**Slide 32**

## District Level Index

- Index based on size, costs, age and needs of particular project
- Projects with highest priority are considered for funding
- Pavements younger than 5 years get low priority by setting age at 1.0 in index equation

11/15/2002 Module 8 32

The district pavement engineer who had several years experience with the pavement management system developed an index based on size of project, cost, age of the project and the needs in terms of traffic and damage level. Projects which have the highest priority, which is the highest index, are considered for funding. The index has a default value so that pavement projects younger than five years automatically get a low priority because the age is set to one year in the index equation.

**Slide 33**

## District Level Index Equation

Index involves:

<u>Length</u>: two lane roadway in miles
<u>Cost</u>: Dollars
<u>Lane factor</u> (LF): 1 for two lanes, 2 for multi-lanes
<u>Age</u>: time since last treatment (age< 5: value 1)
<u>Needs</u>: % of section requiring maintenance

11/15/2002 Module 8 33

The full index equation is given in Reference Manual. The length is defined in miles of two lanes roadway. The cost is defined in dollars and the length factor is set at one for two lane highways and two for multiple lane highways. Age is defined as the time since the last surface treatment or overlay and is defined at one for any age less than five years. The percent needs is defined as the percentage of the overall lane mile length of the section that requires maintenance.

**Slide 34**

## Index Linked to PMS Data

- Length, LF, age and % needs provided by PMS database
- Cost estimates and priority recommendations provided by area engineers
- When area engineer high priority projects conflict with PMIS - pavement is re-inspected and decision made by him/her

11/15/2002 Module 8 34

The index itself is closely linked to the pavement management database as shown in the visual. The length, the lane factor, the age and the percent needs are all provided by the PMS database. The cost estimates and the priority recommendations are provided by the area engineers within the District for the county in question. It should be remembered that in Texas the districts and areas have considerable autonomy. When there is a disagreement between a high priority project from the PMS calculations and the area engineer's estimation, the project is re-inspected and based on the re-inspection the area engineer makes the final decision.

**Slide 35**

## Priority List for Index (Partial)

| Description | Length miles | Age yrs | % Needs | Index | Cost '000$ | Cum. '000 $ |
|---|---|---|---|---|---|---|
| Seal Coat | 4.3 | 9 | 4 | 1.0 | 52.1 | 52.1 |
| Seal Coat | 6.6 | 12 | 4 | 1.0 | 148.1 | 200.2 |
| Seal Coat | 4.1 | 15 | 1 | 1.0 | 47.0 | 247.2 |
| Seal Coat | 6.5 | 11 | 50 | 0.069 | 103.3 | 350.5 |
| SC+Fog Seal | 12.4 | 11 | 36 | 0.028 | 174.2 | 524.7 |
| Slurry Seal | 5.8 | 7 | 91 | 0.024 | 309.5 | 834.2 |
| SC+ Latex | 4.0 | 8 | 30 | 0.013 | 72.8 | 907.0 |

11/15/2002 Module 8 35

Table only serves as example, the actual list contains 32 projects up to cumulative of $7000 and also gives County, Highway, Lane factor and Area priority (between 1 and 9).

**Slide 36**

## Summary of 1997 Program

- 126 projects submitted by area engineers, and prioritized according to index
- Only first 32 projects could be financed with $7,000,000 budget
- For first three projects with index=1 and very low value for %Needs the district overrode the prioritization.

11/15/2002 Module 8 Pavement Maintenance Performance 36

In 1997, the Forth Worth district considered 126 projects, which were submitted by the area engineers and prioritized these according to the index developed. Only the first 32 projects could be financed out of the 7 million dollar budget. Leaving a back log of about 90 projects. The first 3 projects had an index of 1.0 but had a very low value of 4 percent needs, so the district overrode the prioritization and skipped these projects.

**Slide 37**

## Conclusions

- District level index is useful tool for establishing priorities in project selection
- The index makes use of PMIS data
- Ultimate responsibility for selection rests with the district PMS engineer.

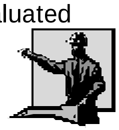
11/15/2002 Module 8 37

Based on the study done in the Forth Worth district of TxDOT, it is clear that individual districts or sub-groups within a DOT can use the Pavement Management data to develop tools for establishing priorities for project selection. The work can either be done at the central office level or by individual districts or agency. Uniformity is desirable. The index in this case makes use of the data available in the TX PMIS database. It is important to note that the PMIS database does not take the final authority of the area engineers or the district pavement management engineer. In this case, the next slide is with DOT on preventive maintenance strategies for CRCP.

**Slide 38**

## Preventive Maintenance Strategies for Continuously Reinforced Concrete Pavements

- Research Study carried out by WisDOT
- Several rehabilitation and preventive maintenance techniques evaluated since 1988



11/15/2002 Module 8 38

The next subject we want to undertake is the description of preventive maintenance strategies used by the Wisconsin Department of Transportation for continuously reinforced concrete pavements. A research study was carried out by WisDOT to evaluate various preventive maintenance strategies. This study began in 1988 and several rehabilitation and preventive maintenance techniques were undertaken.

**Slide 39**

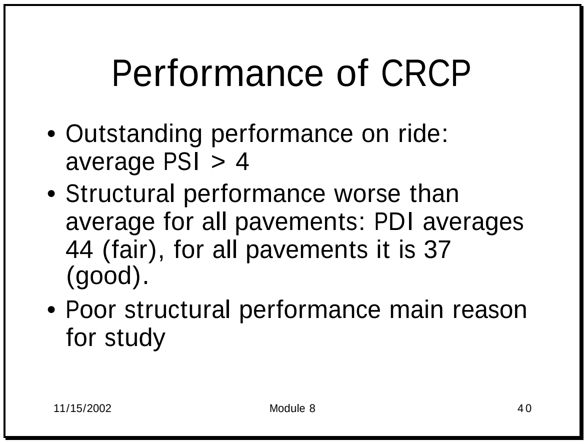
## Use of CRCP by WisDOT

- CRCP only used on high volume roads, 3.5% of total statewide mileage, or 475 miles
- WisDOT has two generations of CRCP:
  - Built with “black” steel in 60’s and 70’s
  - Built with epoxy coated “green” steel between ‘84 and ‘87.

11/15/2002 Module 8 39

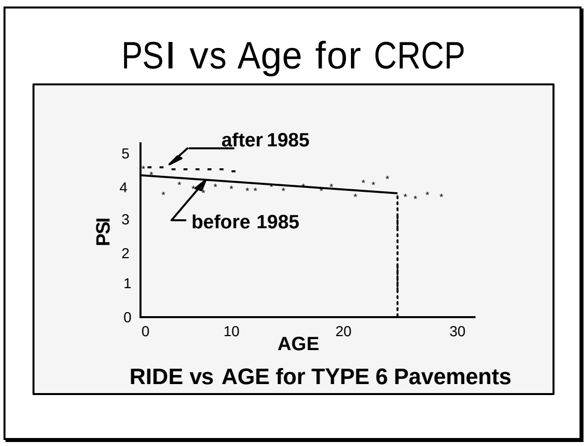
In the Wisconsin Department of Transportation continuously reinforced concrete pavement is used exclusively on high volume roads many of which are Interstates. These represent only about 3.5 percent of the total statewide mileage or about 475 lane miles. In Wisconsin there are two generations of CRCP. In the 1960’s and 1970’s CRCP was built with regular steel or black steel. Because of problems the program shifted to the use of epoxy coated or “green” steel which was used between 1984 and 1987.

**Slide 40**



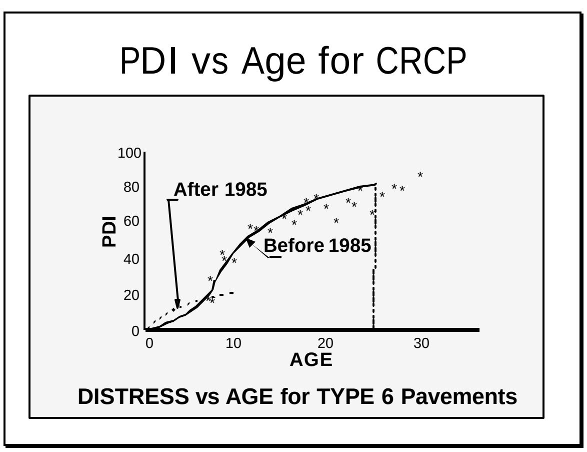

In Wisconsin, the performance of continuously reinforced concrete pavement is generally outstanding with the average ride quality greater than 4.0. On the other hand, the structural performance for CRCP is slightly worse than average with a pavement distress index averaging 44, in the fair category while all pavements average about 37, that is in the good category. The poor structural performance exhibited by these pavements is the main reason that Wisconsin undertook the study.

**Slide 41**




This slide shows a comparison of serviceability index (PSI) vs. age for continuously reinforced concrete pavements in Wisconsin. It can be seen that pavements built after 1985 with epoxy coated steel have higher quality index than those constructed prior to 1985 with regular black steel. 83 percent of the available data is for the black steel pavements. In both cases, the level of deterioration of the serviceability (PSI) index is relatively slow but it is certainly improved with the epoxy coated steel. It's also important to know that the general serviceability (PSI) index for pavements at 25 years still exceeds 3.0 and in most cases exceeds 3.5 which is a very good ride quality. Calculated service life 25 years (see WisDOT contribution in Module 10)
98% of data during first 25 years
83% of available data "black" steel, 17% "green" steel
"black" steel prior to '85, "green" steel after that date
Very good performance with slow rate of deterioration.

**Slide 42**




This slide depicts a pavement distress index vs. age for CRCP. Most of the data for 25 years represents pavements constructed prior to 1985 with regular black steel. You can see an increase in distress beginning about age 8. The distress index rises rapidly before beginning to level off. The data for the 17 percent of the pavements constructed since 1985 shows the distress index that appeared to increase more rapidly at the beginning but has since leveled off and is expected to remain considerably lower than the distress index for the black steel pavements. Considerable structural deterioration for "black" steel. Much better trend for "green" steel.

PDI ratings are: 0-20 very good
21-40 good
41-60 fair
61-80 poor
81-100 very poor

**Slide 43**

### Structural Deterioration of CRCP

- "Black" steel pavements:
  - By age three cracks have formed
  - Steel reinforcement begins to corrode, causing structural problems, such as punch-outs and delamination
- "Green" steel pavements
  - Much less distress development
  - Some diagonal cracking, probably due to local base failures

11/15/2002 Module 8 43

This slide summarizes the structural deterioration of continuously reinforced concrete pavements in Wisconsin. The pavements constructed with regular steel have considerable cracking formed by the third year. Due to the use of salt and other corrosives the steel reinforcement begins to rust causing structural problems such as punch outs and delamination of the pavement surface. Such deterioration requires immediate maintenance and is unsightly even though the overall ride quality remains relatively good. The epoxy steel pavements show a greatly reduced development of distress although some diagonal cracking has been observed probably due to local base failures.

**Slide 44**

### Preventive Rehabilitation Techniques

- Intensive concrete "super" patching
- AC overlays of various thickness
- PCC bonded thin asphalt overlays
- Impermeable membranes + AC overlays
- Rubblize + AC overlay

*Results:*

- *Thin asphalt overlays were the most successful and are recommended as preferred rehabilitation strategy*

This slide summarizes five types of preventive rehabilitation treatments that have been applied to continuously reinforced pavements in Wisconsin. In the results of the five types of rehabilitation undertaken, thin asphalt overlays were the most successful in slowing the formation of distress and in maintaining a smooth riding quality or good service-ability index. These have been recommended as the preferred rehabilitation strategy for future use.

**Slide 45**

### Preventive Maintenance Techniques

- Cathodic Protection of Rebar mat
- Use of corrosion inhibitors in deicing salt

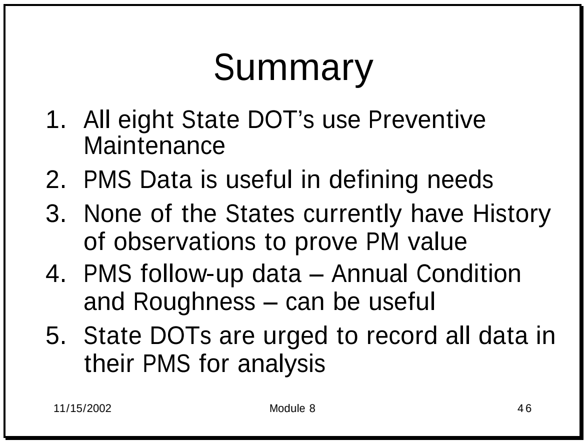
*Results:*

*Both methods were ineffective in reducing distress*

11/15/2002 Module 8 45

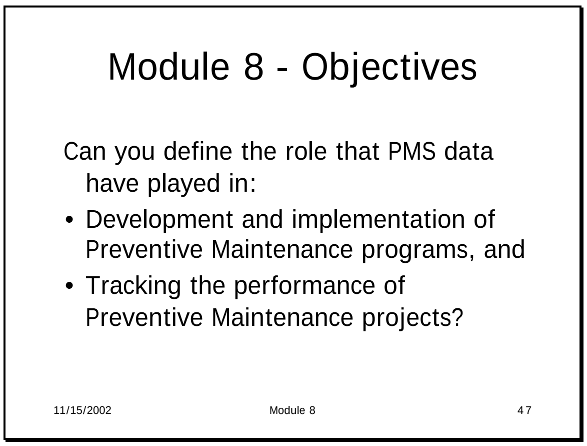
This slide outlines two types of preventive maintenance techniques used. Cathodic protection of the rebar and corrosion inhibitors in deicing salts. Neither of these methods seemed to be effective according to the distress histories recorded in the PMS.

**Slide 46**




This slide summarizes the factors developed in this module. Five points are given on the slide which the instructor may cover by reviewing the slide directly. The instructor should also expand on these items based on his/her own experience. After completing this summary slide, the instructor should allow about 10 minutes of discussion with the students in which they expand on their own knowledge and interest in preventive maintenance and their agency.

**Slide 47**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. Is your agency using PMS to track the performance of preventive maintenance?
2. How are you doing that?
3. Does your organization have a separate budget for preventive maintenance?
4. Does your agency make a clear distinction between preventive maintenance and preservation?

# MODULE 9

# Pavement Preservation Strategies

# Module 9

# Pavement Preservation Strategies (Including LCCA) Instructional Time: 65 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

1. What preservation strategies does your agency use?
2. When do you use Life Cycle Cost Analysis, and when do you just apply standard preservation treatments?
3. What improvements would you like to make?

**Slide 1**

## Module 9: Pavement Preservation Strategies

- Preservation/Rehabilitation Overview
- Examples of engineering analysis in:
  - Pennsylvania State DOT
  - Montana State DOT
- All made possible by PMS data

11/15/2002 Module 9 1

Two major areas are covered in this module. Preservation, that is repairing and extending the life of what you have; and Rehabilitation, that is renewing what you have to begin a new life cycle. Two state examples: PennDOT and Montana DOT are covered.

**Slide 2**

## Module 9 - Objectives

- Define concepts of Preservation
- Define concepts of Rehabilitation
- Recognize interface of these and Preventive Maintenance
- Illustrate concepts in PENNDOT and Montana DOT

11/15/2002 Module 9 2

The objectives of Module 9 are to explain the concepts of preservation and rehabilitation to the students and to define the interface between these two activities and preventive maintenance. The secondary objective is to show the students how the Pennsylvania and Montana DOTs deal with pavement preservation and rehabilitation including life cycle costs analysis of various alternatives. At the end of the session, the students will be able to define how they themselves can undertake these concepts within their agency.

**Slide 3**

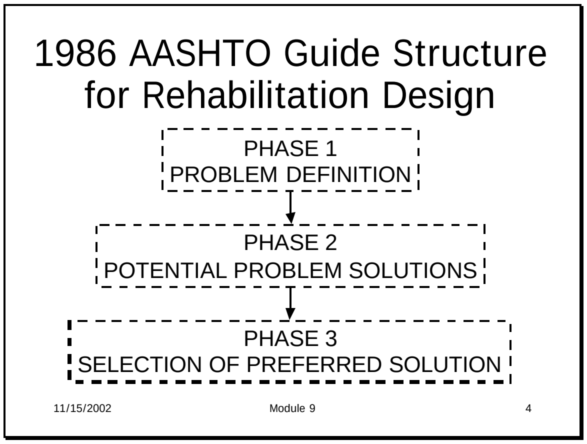
## Preservation & Rehabilitation

- Emphasis shifting from new facilities to maintenance and rehabilitation
- When routine maintenance no longer cost-effective, rehabilitation required
- Array of options make rehabilitation design a complex process
- Considerable amount of analysis and engineering judgement required
- Documented performance histories in PMS database improve design process

11/15/2002 Module 9 3

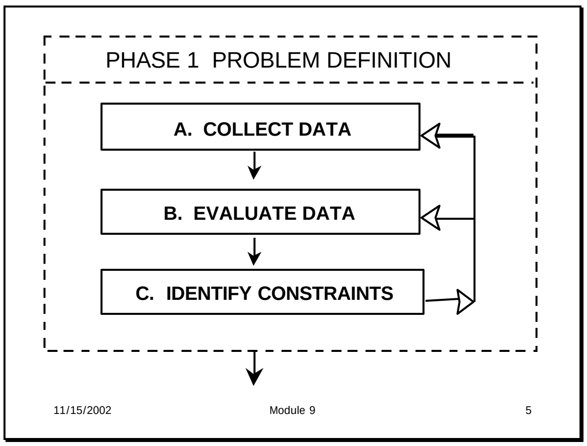
Why is Preservation and Rehabilitation important? The instructor should cover the five bullets shown on the slide and expand based on his/her experience.

**Slide 4**



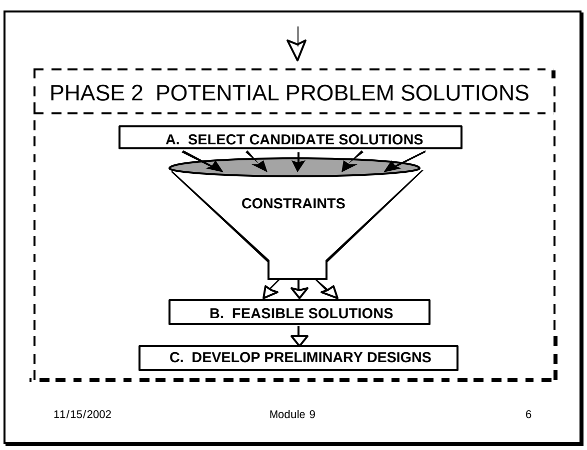

The 1986 AASHTO guide approach is presented in this module because it is widely used by state DOTs. The charts illustrate complete aspects of a rehabilitation method in a three step process and the steps are explained in following slides.

**Slide 5**



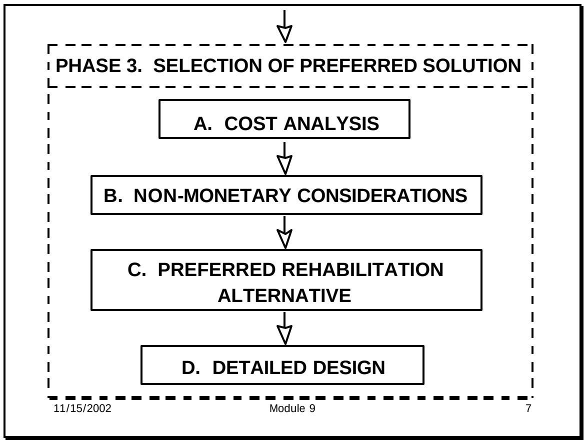

This phase establishes framework for solutions and three tasks are required to properly clarify the problem.

**Slide 6**




The instructor should study and discuss this slide and expand based on his/her own experience.

**Slide 7**




In considering data factors, economic analysis and LCCA, it is essential that data and methodology are compatible with those of the project level PMS. The instructor should expand the discussion of these factors.

**Slide 8**

## Non-overlay Methods

1. Full depth repair
2. Partial depth patching
3. Joint and crack sealing
4. Subsealing and undersealing
5. Grinding and milling
6. Sub-drains
7. Pressure relief joints
8. Load transfer restoration
9. Surface treatments

11/15/2002 Module 9 8

AASHTO Guide classifies rehabilitation as follows:

- Overlay
- Non-overlay
- Complete reconstruction

Several non-overlay methods are shown in the slide and should be covered by the instructor.

**Slide 9**

## Data Collection for Rehab Design Evaluation

1. Delineation of analysis units
2. Drainage evaluation
3. Pavement distress survey
4. Nondestructive testing
5. Field sampling and testing

11/15/2002 Module 9 9

If agency has a network level PMS, some required info may be available from a database but it will always be necessary to supplement this with data taken from their specific project .
If a project level PMS is being used, more detailed data may be available. The AASHTO Guide includes data collection guidelines for evaluating pavement rehabilitation projects. In addition, the FHWA developed a training course on pavement rehabilitation that contains valuable information on pavement repair and rehabilitation methods. As previously discussed, data collection requirements for project level work are more intense than those for network level analysis. Once the data is collected, it should be stored in a project level database.

**Slide 10**

## Analysis Units

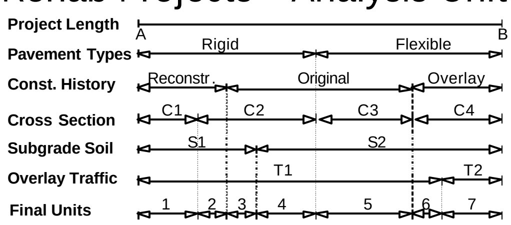
1. Pavement type
2. Construction history
3. Pavement structural characteristics
4. Subgrade soil type
5. Traffic
6. Pavement condition

11/15/2002 Module 9 10

Frequently, the pavement properties will vary along length of project. If these variations are not recognized in selection of rehabilitation alternatives, parts of the project will be over or under designed. This isolates unique factors into separate sections called analysis units.
The instructor should be knowledgeable about the six factors listed above and expand the discussion.

**Slide 11**

## Rehab Projects - Analysis Units



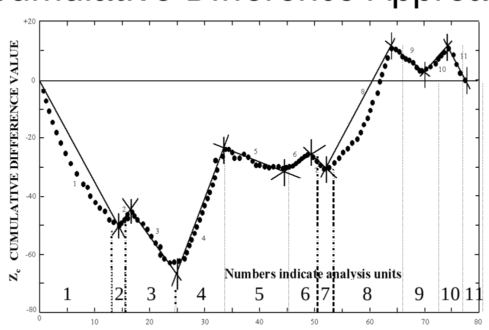

Unit Attributes:

| Unit Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Pavement Type | R | R | R | R | F | F | F |
| Construction Hist. | REC-5 | REC-5 | OR-15 | OR-15 | OR-15 | OL-20 | OL-20 |
| Cross Section | C1 | C1 | C2 | C2 | C3 | C4 | C4 |
| Subgrade | S1 | S1 | S1 | S2 | S2 | S2 | S2 |
| Overlay Traffic | T1 | T1 | T1 | T1 | T1 | T1 | T2 |

This slide illustrates how a project might be divided into seven different analysis units based on differences in pavement types, construction history, cross section, soil type, and traffic.

**Slide 12**

## Cumulative Difference Approach




11/15/2002 Module 9 12

In some cases, the only or best information available is a recent deflection survey and/or distress survey. Such data can be used as follows to establish analysis units, deflection or pavement distress data can be used. This method has following steps:

- Plot response variable along distance
- Transform or normalize variable into new parameter Zc, defined as difference between area under response curve at any distance and total area developed from overall project average response at same distance
- Plot Zc against distance, where slope of resulting curve changes sign define boundaries of analysis units, see graph.
- Review location of boundaries to ensure sections are logical.

**Slide 13**

## AASHTO Performance Models

- Restoration Performance Models
  - Mostly for rigid pavements
- Overlay Performance Models
  - Mostly for flexible pavements

11/15/2002 Module 9 13

Models for predicting performance of rehabilitation strategy are essential for design of rehabilitation strategy. For new pavements the AASHO Road Test provides us with a great deal of information but for rehabilitated pavements a universally accepted reliable set of performance models is not yet available.
Some states have developed a historical PMS database with extensive performance data for rehabilitated pavements. New tools such as Visual Modeler software system are available to help analyze historical PMS data to develop such mo dels for rehabilitation.

**Slide 14**

## Summary

- Project evaluation
  - PMS data for location/condition
  - Additional investigation
  - Deflection testing
  - Field samples
- Performance models

11/15/2002 Module 9 14

The PMS database can provide critical input data to the preservation and rehabilitation process. Lack of good performance models for rehabilitation techniques is area of strong potential research for the future. For second and third analysis periods after pavement is rehabilitated various contributions to this course, treating specific project level pavement management systems, give examples of rehabilitation models and a cohesive project level pavement management approach. The pavement manager is warned at this point, not to adapt one set of models from one methodology and use it with another set of models from another methodology. The total project level pavement management system mu st be cohesive for results of pavement management process to be effective.

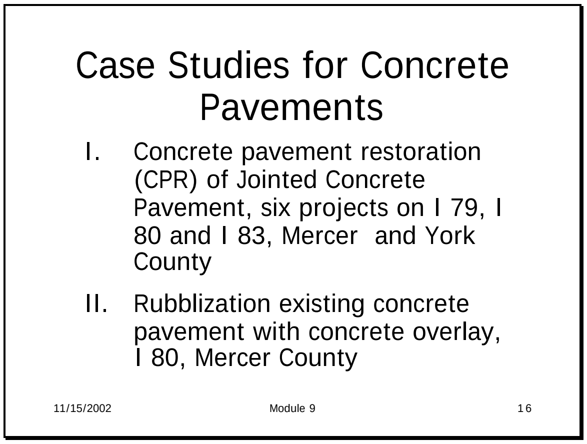
**Slide 15**

## PennDOT - Selecting Concrete Pavement Rehabilitation Strategies

11/15/2002 Module 9 15

This example comes from the state of Pennsylvania. The basic details of the PennDOT PMS was covered in Module 4.
This part of the module is extracted from an unpublished 1996 paper written by Gaylord Cumberledge of the Pennsylvania DOT and Dennis A. Morian formerly of Penn Dot [Cumberledge 96]. It is a good example of using both network and project level PMS data for rehabilitation evaluation and design.

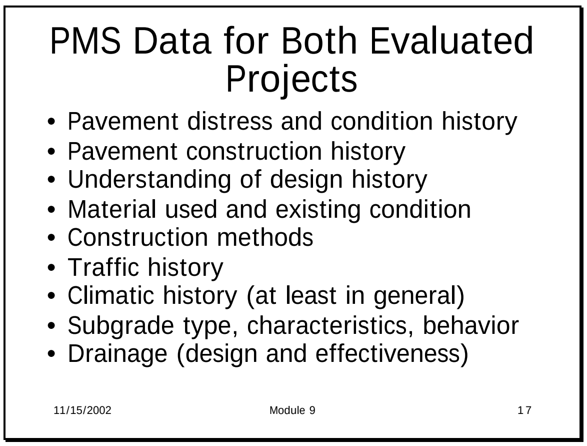
**Slide 16**





Two case studies of concrete pavements are covered as shown in the slide. These examples show that substantial additional work was needed to enhance pavement management data in making assessments of rehabilitation methods.

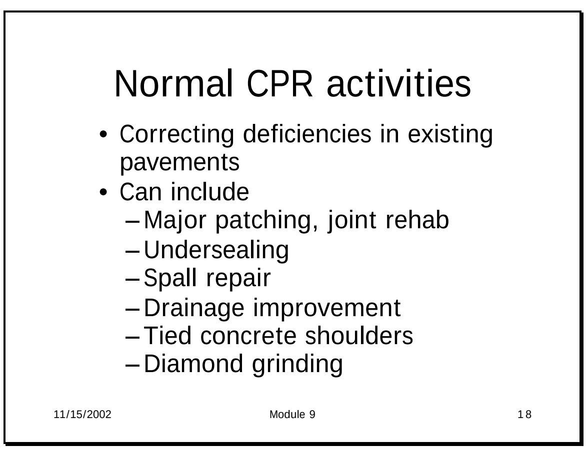
**Slide 17**





Penn DOT has a wealth of data and the nine items listed here were used in both projects.

**Slide 18**





CPR stands for Concrete Pavement Restoration. It can include the items listed on the slide. The instructor should expand on these based on experience. Often these projects exceed one million dollars per four lane mile and result in extensive traffic delays and lane closures.

**Slide 19**

## CPR in Case Study I

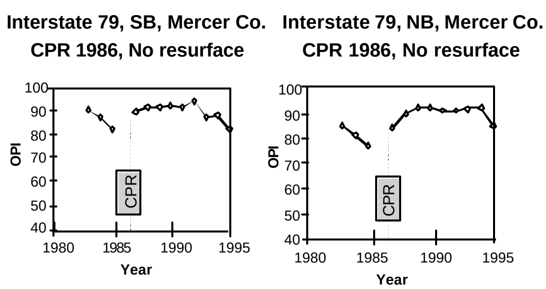
- Joint rehabilitation @ 18.5 m (61.5') centers
- PCC spall repair, mainly at cracks
- Diamond grinding of bumps
- Tied concrete shoulders added
- Six CPR-Projects carried out between 1984 - 1986

11/15/2002 Module 9 19

Pavement section was determined to be a good CPR candidate containing minimal structural distress at time of rehabilitation. Instructor reviews the slide.

**Slide 20**

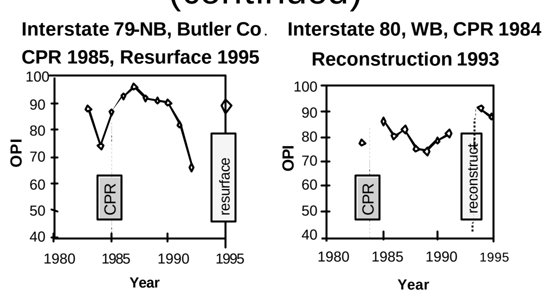
## Performance of 6 CPR Projects




The slide shows the change in overall performance index for two sections. Discuss the difference before and after CPR Action in 1986. CPR has performed well for 10 years.

**Slide 21**

## Performance of 6 CPR Projects (continued)

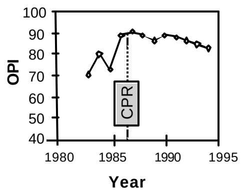



Explain slide in same way as previous slide.
On IH 79, the data shows that failure accelerated in 1989 only four years after CPR.
On IH80 the data looks good but nevertheless, the District chose to reconstruct in 1993 indicating some obvious problem.

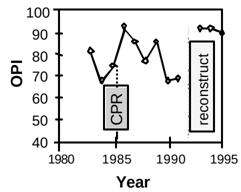
**Slide 22**

## Performance of 6 CPR Projects (continued)

**Interstate 83, NB, York Co.**
**CPR1986, No resurface**




**Interstate 80, NB, Mercer Co.**
**CPR1985, Reconst. 1992**




Explain slide.

- IH83 – CPR has performed well.
- IH80 did not perform well as shown and was rebuilt in 1992.
- PennDOT basically concluded that CPR was not cost effective and worked reasonable well only 50% of the time.

**Slide 23**

## Case Study II Rubblization and Concrete Overlay

- Project carried out in 1986-87
- Length of project 8 km (5 miles)
- Part of Interstate 80 in Mercer County

11/15/2002 Module 9 23

Our next case study in Pennsylvania covers rubblization of 5 miles of a concrete pavement as shown on the slide.

**Slide 24**

## History - Case Study II

- Concrete pavements constructed in late 1950's
- Poor subgrade and high traffic loadings
- Late 1970's & early 1980's 75 km (47 miles) of various rehabs
  - 48 km (30 miles) of (partial) rubblization with unbonded CRCP overlay (unsuccessful)
  - 19 km (12 miles) of crack and seating with 330 mm (13") AC overlay (unsuccessful)
  - 8 km (5 miles) with straight 254 mm (10.5") AC overlay (this project)

11/15/2002 Module 9 24

Unbonded CRCP overlay developed punch-out distresses before construction activities were finished because original rigid pavement was never successfully stabilized. Asphalt overlay,
problems with 13" asphalt overlay: by 1988 an unsuccessful fog seal had been applied, and a mill and resurfacing strategy had been applied twice.

**Slide 25**

## Problems with AC overlaid Concrete Pavement

- Poor subgrade support
- Did not place .3 to .6 m (1 to 2 ft) granular blanket called for in original design
- 18.5 m (60.7 ft) joint spacing
- Severe stripping and damage of reflective cracks in AC above joints, resulting in depressions

11/15/2002 Module 9 25

Original concrete pavement constructed in late 1950's. Instructor review the slide content.

**Slide 26**

## Construction Details Case Study II

- Removed 267 mm (10.5") asphalt overlay
- Rubblized existing concrete into much smaller fragments than with earlier tried cracking and seating
- 305 mm (12") Jointed concrete overlay
- 6.1 m (20') Skewed joint and tied shoulder
- New pavement drains

11/15/2002 Module 9 26

Strategy to remove existing asphalt overlay and effectively seat the concrete pavement on subgrade by fracturing the pavement into small fragments. Earlier experience with cracking and seating of a 61.5' jointed concrete pavement frequently resulted in reflective cracking at old joints.

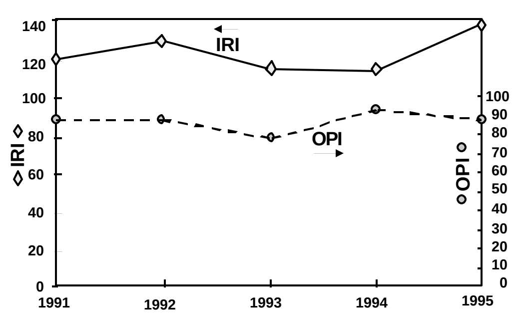
Advantages of design.

- Improved k value as compared with native subgrade.
- Enhanced drainage capability to remove water in subgrade.
- Increased elevation separation of pavement from subgrade water table.
- Placed traffic loads farther from slab edge with concrete shoulders

In addition, in-place recycling of existing concrete pavement could be accomplished.

**Slide 27**

## Performance of Rehab of Case II




Performance history 1991-1995 for IRI and OPI, note that scale for IRI on left, for OPI on right. No data available prior to 1991. Concrete overlay resulted in good pavement performance; indications at this time are that this performance will continue. OPI has remained fairly constant, roughness (IRI) has increased only slightly. In 1996, the most noticeable distress is wheel path wear resulting from studded tire use.

**Slide 28**

## Key to Success of CPR
(Concrete Pavement Restoration)

- Pavement is basically sound
- OPI > 70 (Overall Performance Index)
- Proper evaluation of pavement condition and history using PMS
- Knowledge of performance of previous CPR's

11/15/2002 Module 9 28

This slide shows the four factors that are keys to potential success of CPR. Even with these factors, success is not insured as the case study illustrates.

**Slide 29**

## Conclusions

- Concrete Pavement Restoration can sometimes (not always) increase service life of pavement as long as structurally sound prior to restoration
- For concrete pavement with structural failures a thorough rubblization & effective seating of existing pavement with 305 mm (12") concrete overlay, 6.1 m (20') skewed joints and tied shoulders has so far provided good solution.

11/15/2002 Module 9 29

Additional points of interest:
Don't look at pavement structure in isolation; also consider drainage aspects, joint design, and effects of shoulders. The pavement in case II is still only 12 years old also in case of asphalt overlay a thorough rubblization and seating is required. Consider avoiding concrete pavements in case of very poor subgrades.

**Slide 30**

## Montana State DOT's Engineering Analysis Elements

- Module 9:
  - Overview of MDT PMS
  - Optimize preservation through LCCA of various alternatives
- Module 10:
  - Integration of Maintenance in MDT's PMS

11/15/2002 Module 9 30

The next example is from Montana. First, the instructor should outline the basic MDT PMS and cover their use of life cycle cost analysis and a second MDT example is given in Module 10.

**Slide 31**

## Background on MDT

(Montana Department of Transportation)

- Montana is the fourth largest state
- Total population about 800,000
- Billings is the largest metropolitan area (population 75,000)
- Roadway network over 54,400 km (34,000 miles)
- MDT is responsible for approximately 38,400 km (24,000 lane miles)

11/15/2002 Module 9 31

The instructor explains the slide.

**Slide 32**

## MDT Organization

- Five districts
- Eleven maintenance divisions
- PMS section is responsible for all NHS, state and local federal-aid roadways

11/15/2002 Module 9 32

The instructor explains the slide.

**Slide 33**

## PMS Overview

- Data Collection and Management
  - Inventory
  - History
  - Condition
  - Traffic
- Pavement Management Analyses
- PMS Update/Feedback Process

11/15/2002 Module 9 33

Data collection and management component of PMS based on procedures that have developed and evolved over past 12 years. Processes have been refined and incorporated into modern client/server relational database management structure for use in updated PMS.

**Slide 34**

## Condition Survey

- 60 m (200 ft) sample of visual distress, taken at every milepoint using a walking survey
- Sections are easy to locate in the field and remain consistent from year to year
- Network sampling once per mile to estimate condition of the network
- Condition surveys are recorded & stored in the database on a per mile basis

11/15/2002 Module 9 34

The instructor explains the slide. By maintaining condition data in its raw form, PMS can adjust project section breaks without losing condition form.

**Slide 35**

## Deflection Testing

- Network-level structural rating is performed by routine deflection testing using a Road Rater
- Network-wide structural information is used to help identify structural problems early
- Assigned minor rehabilitation and maintenance treatments may be adjusted to extend the life of the pavement before major rehabilitation or reconstruction is required based on deflection measurements

11/15/2002 Module 9 35

The instructor explains the slide.

**Slide 36**

## Traffic Information

PMS stores traffic information containing:

- AADT
- ESAL estimates on the network
- Used for network and project level analysis
- Traffic counts, classifications, and truck weight information collected by the Traffic Division and stored in central Oracle database

11/15/2002 Module 9 36

The instructor explains the slide.

**Slide 37**

## Database System

- Entire pavement management database resides on centralized relational database system using Oracle 7.2
- PMS has client/server configuration, ideal for maintaining single, well controlled database that all users can access
- PMS also vehicle to allow effective coordination and integration among different sections at MDT
- PMS analysis software resides on networked microcomputers, no downloading required.

11/15/2002 Module 9 37

The instructor explains the slide.

**Slide 38**

## Database System (Cont.)

- PMS Section responsible for maintaining most of PMS related data.
- Specific data tables may be maintained by other sections within Department.
- Coordination between PMS Section and other Sections provides strong incentive for good communication.
  - (e.g., traffic information & contract work data is maintained by other groups within MDT).
- Information Services Bureau is coordinator & overall database administrator.

11/15/2002 Module 9 38

Examples of data tables maintained by other sections:

- Traffic data table owned by Traffic Section of Planning Division
- Pavement Condition data owned by Pavement Management Section in Materials Division

**Slide 39**

## Pavement Management Analyses

- Pavement Condition Analysis
- Remaining Service Life
- Pavement Performance
- Investment Analysis
- Project Selection

11/15/2002 Module 9 39

Five types of analysis are used. PMS spans many groups and acts as a coordinating and communicating tool. PMS has information and results that benefit large portion of the organization, including maintenance supervisors and crews.

**Slide 40**

## Pavement Condition Analysis

- Condition indices based upon individual distresses or any combination, they include:
  - Roughness
  - Fatigue cracking
  - Environmental cracking
  - Rutting
  - Structural index
  - Safety index
  - Combined roughness and cracking
  - Overall pavement index
- Indices essential for remaining service life analysis, decision trees, multi-year prioritization and optimization, etc.

11/15/2002 Module 9 40

For the analysis of pavement condition use is made of condition indices, based upon individual distresses or any combination thereof. Weighting factors, deduct values and threshold values used in the analysis models have been customized by MDT to fine tune the analyses based on improved experience. Overall condition score is only adequate for network levels but not for selecting projects and specific actions.

**Slide 41**

## Pavement Performance Models

- Pavement performance models required for network level analysis
- Structure of models dependent on type of network level analysis being used
- Deterministic models used for estimating remaining service life, project selection, treatments assignment and prioritizing projects over multi-year period
- Models also used for risk based life-cycle cost analysis system

11/15/2002 Module 9 41

Integrated pavement performance modeling software helps MDT to develop required models from databases.

**Slide 42**

## Inputs for LCCA (Life-Cycle Cost Analysis)

- Pavement performance inputs
  - measured or estimated as needed
- Cost inputs
  - define magnitude of costs for each action
- Project inventory
  - defines location, size, traffic, environment and other parameters that are independent of alternative treatments

11/15/2002 Module 9 42

Visual/LCCA software developed for MDT by Texas Research and Development, Inc. incorporates life cycle cost analysis procedures. Each pavement project to be rehabilitated or reconstructed is analyzed for life-cycle costs. An alternative is a specific design that meets requirements of the project which can have any number of alternatives.

**Slide 43**

## Obtaining Pavement Performance Inputs

- Currently enough data available to estimate mean lives of various “typical” treatments in database
- However variability estimates often difficult to make because of low number of data points for treatments. Additional engineering judgement used to estimate variability in treatment lives

11/15/2002 Module 9 43

The instructor explains the slide.

**Slide 44**

## Obtaining Cost Inputs

- Cost inputs retrieved from selected projects similar to project being studied
- Cost inputs also retrieved from contract administration files and bid lists for unit costs
- Composite estimates of treatment costs estimated from the collected data

11/15/2002 Module 9 44

The instructor explains the slide.

**Slide 45**

## Example with 2 Alternative Rehabilitation Strategies

Project length 9.3 km (5.8 mi), width 9.6 m (32 ft), Design Life 30 yrs

| Yr | Strategy 1 | Strategy 2 |
|---|---|---|
| **0** | **Thin Resurfacing (4yrs)** | **Reconstruction (20 yrs)** |
| **4** | **Thin Resurfacing (4yrs)** | |
| **8** | **Reconstruction (20 yrs)** | |
| **20** | | **Thick Overlay (15 yrs)** |
| **28** | **Thin Resurfacing (4yrs)** | |

11/15/2002 Module 9 45

This slide shows two of the strategies that were examined in this study. Many others were looked at. A strategy is made up of a series of actions over the lie of the pavement.

**Slide 46**

## Treatment Costs

Cost in '000 $

| Treatment | Construct Cost | Administr. Cost | Maintenance Cost | User Delay Cost** |
|---|---|---|---|---|
| **Thin Resurfacing** Design Life 4 yrs | 1,200 | 250 | ---- | 99.5 |
| **Reconstruction** Design Life 20 yrs | 2,400 | 350 | ---- | 199.0 |
| *Crack Seal (Years 3,10,17)* | | | *11.0* | *6.6* |
| *Seal and Cover (Years 7, 14)* | | *40.0* | *200.0* | *11.1* |
| **Thick Overlay** Design Life 15 yrs | 1,800 | 350 | ---- | 132.7 |
| *Crack Seal (Years 3, 9, 13)* | | | *11.0* | *6.6* |
| *Seal and Cover (Years 6, 11)* | | *40.0* | *200.0* | *11.1* |

- Costs for various treatments along with associated maintenance activities/costs.
- Variability of these costs should be quantified as much as possible.

Other uncertainties are:

- Traffic growth rate
- Treatment life
- Discount rate

As example only sensitivity of discount rate will be given.

**Slide 47**

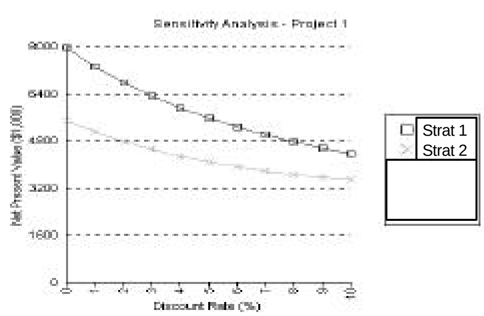
## Simulation Life Cycle Cost Analysis Results

| Alternative | Net Present Value | Standard Deviation | Minimum Likely Value | Maximum Likely Value |
|---|---|---|---|---|
| 1. (3Thin Surf+Rec) | $4,677,955 | $302,302 | $4,085,443 | $5,270,467 |
| 2. (Rec.+Thick Ovl) | $3,669,242 | $168,943 | $3,338,114 | $4,000,370 |
| Difference (1-2) | $1,008,713 | $133,359 | | |

NPV (Net Present Value) of Alternative 2 is considerably lower than that of Alternative 1.
The expected distribution of life-cycle costs is also smaller as shown by standard deviation.
The results for the simulation and scenario analysis are visualized in graph on next slide. Note that the analysis method used, does consider uncertainty in estimating costs.

**Slide 48**

## Sensitivity of Discount Rate

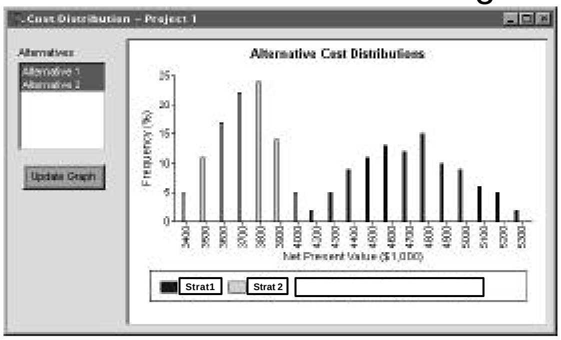





This slide compares the net present value versus discount rate for two alternatives.

**Slide 49**

## Cost Distributions of Strategies




11/15/2002 Module 9 49

Explain graph from Visual LCCA

- Strategy 1, Strategy 2
- Distribution as result of variability of:
- Cost of treatments
- Traffic gro wth rate
- Treatment life

**Slide 50**

## Results of LCCA

**Strategy 2 is clearly the better alternative in this example**

- Mean (expected) life cycle cost smaller than for Strategy1
- Variability for Strategy 2 less, so this alternative less "risky"
- Sensitivity of Strategy 2 to discount rate (which is uncontrollable) also lower

11/15/2002 Module 9 50

The instructor explains the slide.

**Slide 51**

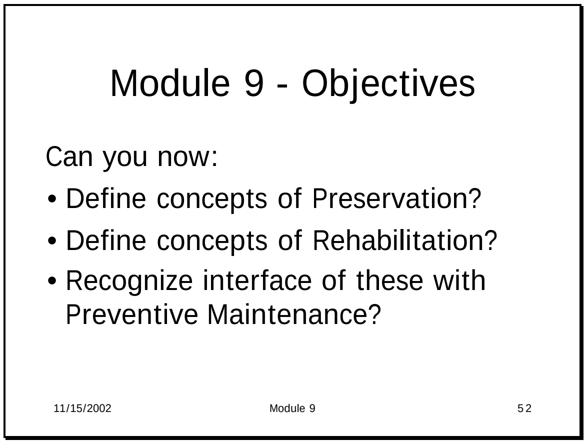
## Conclusions

- Risk based life-cycle cost methodology and corresponding Visual LCCA software form effective tool for LCCA
- The analysis would be cumbersome without the availability of a reliable and comprehensive PMS Database

11/15/2002 Module 9 51

The instructor explains the slide and should allow time for discussion.

**Slide 52**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant's learning accomplishments.

1. What preservation strategies does your agency use?
2. When do you use Life Cycle Cost Analysis, and when do you just apply standard preservation treatments?
3. What improvements would you like to make?

# MODULE 10

# Pavement Maintenance Effect on Performance

# Module 10

# Pavement Maintenance Effect on Performance

# Instructional Time: 60 minutes

It is important for the instructor to encourage the participants to refer to their Reference Manual through out the presentation, especially for detailed information and for those slides with screenshots that are difficult to read in the small prints of the slides in the Participant Workbooks. This will allow the participants to become familiar with the manual by the end of the course.

Participant Questions

1. Are maintenance activities recorded in your PMS?
2. Does your agency have a Maintenance Management System?
3. If so, how is MMS linked to PMS?

**Slide 1**

## Module 10: Pavement Maintenance Effect on Performance

- Overview of Maintenance Systems
- Maintenance Management Overview
- Examples of engineering analysis in Montana State DOT

11/15/2002 Module 10 1

Module 10 is the last major module in the course. It covers pavement maintenance and the effective maintenance on performance of pavements. There are 3 major aspects of this module:

1. First there is an overview of maintenance in general;
2. Second is an outline of maintenance management system and
3. Finally, examples of engineering analysis in Montana State DOT are presented.

**Slide 2**

## Objectives of Module 10

- Show relation of maintenance elements & PMS
- Outline concepts of MMS
- Summarize various aspects of maintenance
- Apply engineering analysis to maintenance

11/15/2002 Module 10 2

The objectives of Module 10 are to outline maintenance as related to PMS and then to formulate in the minds of the participants an overall concept of maintenance management systems and to define how these elements relate to each other and to pavement management in general. A secondary objective is to summarize the various aspects of maintenance, preventive, corrective and preservation to clarify these for the participants. A further objective will demonstrate the application of engineering analysis to maintenance management and related performance models.

**Slide 3**

## Overview of Maintenance Concepts

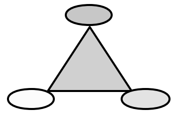
- Definition of maintenance varies by agency
- Maintenance and rehab are closely related
- Many agencies separate the two by budget definitions

11/15/2002 Module 10 3

As outlined in this slide, the definition of maintenance varies by agency. Maintenance and rehabilitation are closely related and in general, agencies can desperate maintenance and rehabilitation by budget definitions rather than technical definitions. Availability of funds often controls the definition of work done as maintenance.

**Slide 4**

## Maintenance Policy Factors



- Funds available
- Historical precedent
- Political and Organizational considerations

11/15/2002 Module 10 4

There are 3 policy factors that relate to maintenance. The funds that are available is probably the primary factor, second is historical precedence and finally political and organizational considerations have a major impact on maintenance that is carried out in a DOT.

**Slide 5**

## Funds Available

- Available funds usually applied to fill most extreme/most expensive needs
- Remaining budget then proves inadequate to serve total area involved
- Consequently routine maintenance suffers, leading to downward cycle of deterioration
- Cycle prevented by budgeting for maintenance as part of pavement management

11/15/2002 Module 10 5

The slide outlines 4 major elements related to funds available for maintenance. The instructor may read directly from the slide and expand on these based on his/her own experience.

**Slide 6**

## Historical Precedent

- Until recently maintenance not widely researched
- As a result many maintenance methods adopted without proof of their general applicability or effectiveness
- Highway system not a homogeneous entity, e.g. Interstates construction ‘54-’60 with subsequent high-quality maintenance, originally at low cost. By mid-’70 very costly

11/15/2002 Module 10 6

The aspects of maintenance are basically heavily dependent upon historical precedent. The slide outlines 3 aspects of this historical precedent and the instructor may read directly from them and expand on the concepts based on his/her experience.

**Slide 7**

## Political and Organizational Considerations

- In difficult financial times maintenance often sacrificed
- In case of unusual event (extreme winter), budget often substantially reduced
- Two hurdles for integrating management in central office with decentralized maintenance operations in the field:
  - Time delay between planning and execution
  - Different location and culture

11/15/2002 Module 10 7

There are 3 major aspects of political and organizational aspects of maintenance. These are covered on the slide and the instructor may review those based on his/her experience.

**Slide 8**

## Policy Variations

- Inadequate funds result in local field manager personal preference choice in spite of policy
- Routine maintenance gets preference over preventive maintenance
- Visible condition such as mowing and trash pick-up get served first

11/15/2002 Module 10 8

Policy variations are a major aspect of maintenance. The average highway maintenance engineer is more interested in maintaining the pavements under his/her jurisdiction than in any policies or rules laid down upon him/her. This slide outlines three major policy variations that the average maintenance engineer is concerned with. The instructor should review these based on the slide and expand on them based on his/her experience.

**Slide 9**

## Analysis of Effects of Policy Changes

Use PMS data to:

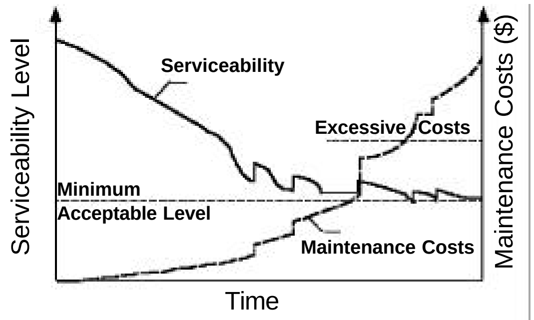
- Analyze effect of budget changes on highway system (network level)
- Reanalyze any given pavement due to delays from budget changes (project level) and identify possible alternative actions

11/15/2002 Module 10 9

The highway department may use pavement management systems data to analyze the effects of budget changes on highway performance at the network level and may reanalyze any given pavement section at the project level based on the effects of individual maintenance activities. It’s important for the instructor to discuss and emp hasize these aspects.

**Slide 10**

## Unacceptable Maintenance Costs




11/15/2002 Module 10 10

This slide illustrates that while serviceability deteriorates, it may be kept above a minimal acceptable level by expending maintenance funds. However, when those maintenance costs become excessive we then have an un-economical situation and maintenance costs should be kept within boundaries by appropriate use of pavement management.

**Slide 11**

## Evaluation Decision Criteria

- Single distress or performance index
  - Threshold levels often act as trigger values for required maintenance action
- Combination index
  - Useful for overall analysis and ranking at network level,
  - Limited use for maintenance

11/15/2002 Module 10 11

This slide points out that evaluation decisions are made either based on a single distress index or a combination index. The instructor may review the slide directly based on his/her experience and expand on the bullet points.

**Slide 12**

## Feedback to PMS

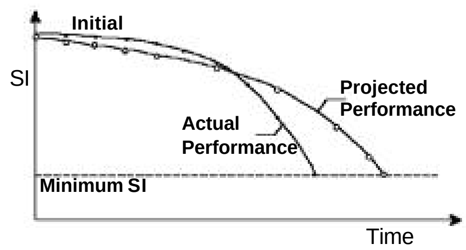
- Programming, planning and execution of maintenance activities
- Evaluation of maintenance models

11/15/2002 Module 10 12

The feedback of maintenance information to a pavement management system is used to upgrade planning and programming decisions of maintenance expenditures and also to evaluate maintenance predictive models. One of the big problems with maintenance in general has been that it has not been appropriately modeled and dealt with in a mechanistic way.

**Slide 13**

## Projected/Observed Performance

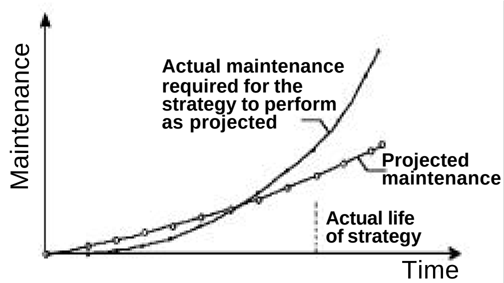



11/15/2002 Module 10 13

This slide points out that projected performance is often idealistic and that in effect actual performance is less than projected by the idealistic models often used in historical predictions. This reduction in performance in actuality often results in the need for additional maintenance.

**Slide 14**

## Projected/Observed Maintenance History




11/15/2002 Module 10 14

This slide depicts the relationship between projected maintenance that is often idealistic and the actual maintenance that is often required for pavements which tend to deteriorate faster than predicted. Actual life of the strategy may depend upon the maintenance required.

**Slide 15**

## Problems with Current Maintenance Data

- Actual maintenance performed can be difficult to assess
- Records often “generalized" to average values rather than actual work on a bad section
- Costs of maintenance performed even more difficult to obtain, particularly for small portions of a section

11/15/2002 Module 10 15

This slide outlines 3 bullet points related to problems that are associated with current maintenance data. The instructor should read directly from the slide and expand on this information based on his/her experience.

**Slide 16**

## Maintenance Summary

- Maintenance can significantly influence pavement performance
- Proper maintenance management essential for effectiveness & efficiency
- Maintenance policies, costs, economics & decision criteria play major role
- Much needed compatibility with pavement management systems requires further efforts



This slide outlines 4 bullet points that are related to the summary of maintenance information. The instructor should read directly from the slide based on his/her experience.

**Slide 17**

## The Importance of Maintenance Transcends PMS alone

- There are many operating details that should be dealt with
- This is done through a Maintenance Management System (MMS)



Maintenance is so important to pavements and to DOTs in general that it certainly transcends pavement management alone. There are many operating details and other elements of the highway system that need to be dealt with. This is generally done with a maintenance management systems or MMS.

**Slide 18**

## MMS deals with other factors in addition to Pavements

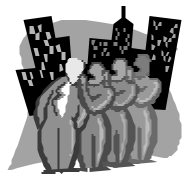
- Right of Ways
- Bridges
- Signs, markings
- Drainage structures
- Equipment
- Materials
- Etc.



MMS must deal with other factors in addition to maintenance. The instructor should discuss the items on the slide based on his/her experience.

**Slide 19**

Maintenance Management Systems have Close Ties to PMS



11/15/2002 Module 10 19

Maintenance management has close ties to PMS. The instructor should review the reference documents with respect to maintenance management systems and should expand on this slide and the introduction of the concept based on his/her knowledge.

**Slide 20**

MMS Objectives

- Plan, direct, and control maintenance activities in order to achieve acceptable level of service (LoS)
- Evaluate methods and materials so that economical & efficient practices are developed
- Acquire and report maintenance cost data so that realistic unit costs for specific sections may be determined

11/15/2002 Module 10 20

This slide outlines the objectives of the MMS in 3 bullet points. The instructor should review these bullet points and expand on them based on his/her knowledge.

**Slide 21**

Purpose of MMS

- Exercise control over budget and maintenance program
- Quantify maintenance needs
- Identify resources to meet those needs
- Determine Standards and Set Priorities
- Plan and manage work
- Monitor Performance

11/15/2002 Module 10 21

This slide outlines 6 purposes of a maintenance management system. The instructor should outline the bullet points from the slide and should expand on these comments based on his/her experience and the reading of the reference document.

**Slide 22**

## MMS Modules

- Network Analysis – Planning & Budgeting
- Work Management – Daily/Weekly Schedules
- Contracted Maintenance
- Labor Management
- Equipment Management
- Materials Inventory Management
- System Administration

11/15/2002 Module 10 22

This slide outlines 7 modules that are good maintenance management systems should include. The instructor should review those modules and expand on the details based on his/her reading of the referenced document and their experience.

**Slide 23**

## Analysis Module

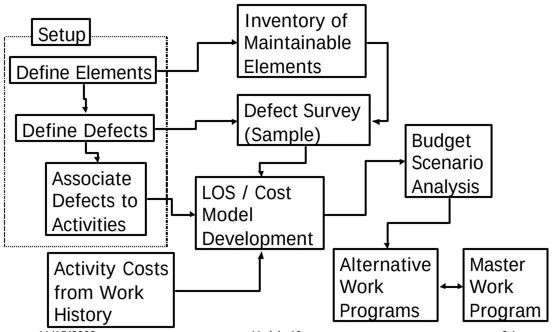
- Maintenance Rating Program
  - Inventory
  - Defects
- Level of Service assessment
- Work Plan Development
- Budgeting
- Tracking Expenditures

11/15/2002 Module 10 23

The Analysis Module is important in dealing with a Level of Service assessment. The data is based on a maintenance rating program involving both inventory and defect information. The Analysis Module is used to develop a work plan for budgeting purposes and also for tracking expenditures in the long term.

**Slide 24**

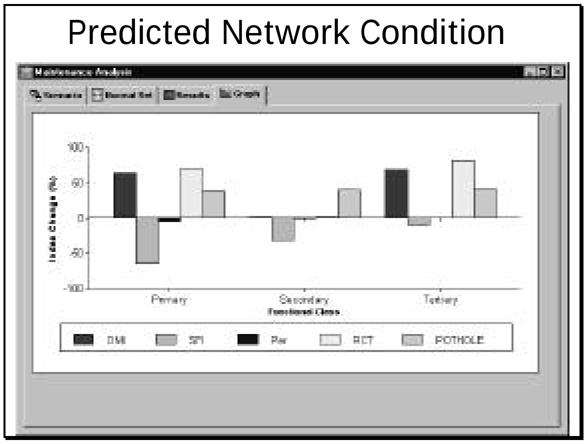
## Level of Service Analysis




11/15/2002 Module 10 24

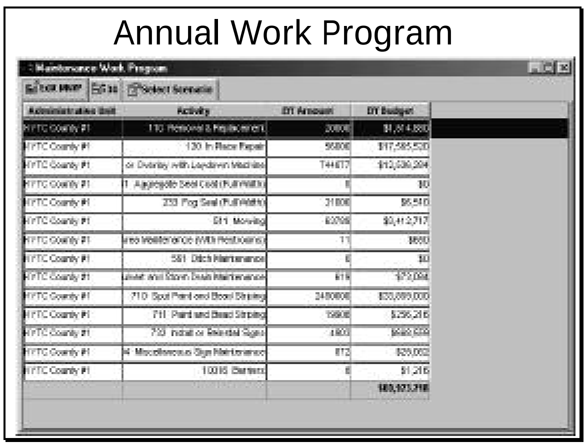
This slide outlines the flow of information in a level of service analysis. The instructor should review the reference document and the slide and should discuss the details for the class based on his/her experience.

**Slide 25**




Network condition is an important aspect of a network analysis. A good maintenance management system makes it possible to predict network condition and should be visually capable of displaying the information as indicated in this slide.

**Slide 26**



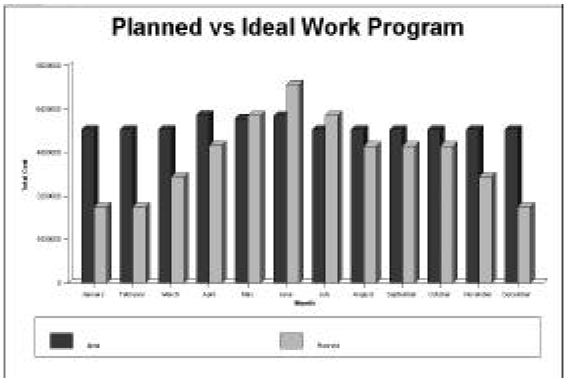

This slide illustrates a print out typical of the kind of annual work program that might be developed in a good maintenance management system. This is of course a summary version of the details that are in the actual computer print out of the program.

**Slide 27**


Any good maintenance force has to spread the work over the various seasons, otherwise all the work builds up in the summer months and this creates a significant unbalance in workforce requirements. This is a typical plot of seasonal activity that can be developed from a good maintenance management system with a good analysis program.

**Slide 28**

## Work Program Comparison




This is a graphic of a work program comparison showing planned vs. ideal work activities. This makes it possible for the maintenance engineer to understand better how his program is functioning as compared to the planned or ideal requirements.

**Slide 29**

## Work Management Module

- Daily/Weekly Work Planning
  - Labor, Materials and Equipment
  - Work activity and location
- Work Accomplishment

11/15/2002 Module 10 29

A good work management module deals with daily and weekly work planning including labor materials and equipment as well as work activity and its location along the network.
Finally, it should also be able to record work accomplishments and how that work accomplishment compares to the initial planning and the budgets.

**Slide 30**

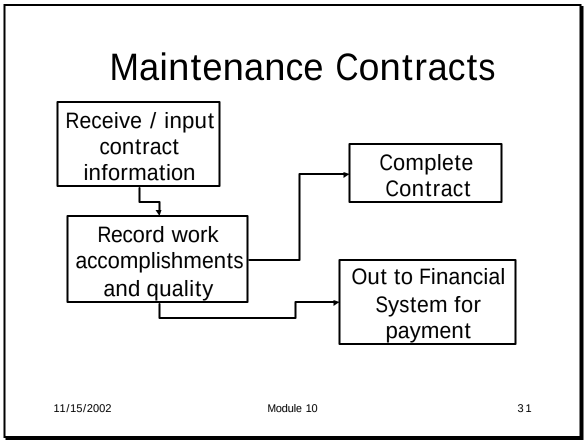
## Contracts Module

- Plan contract details
- Monitor Contract Work
- Comparison of Contract vs. State Forces work

11/15/2002 Module 10 30

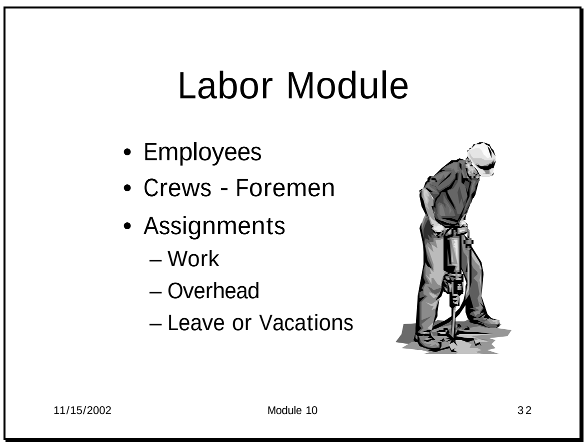
The contracts module makes it possible for the maintenance department to deal with maintenance by contract more successfully. First, it starts out by giving information on contract details planned, then summarizes the maintenance of contract work and finally, allows the maintenance group to compare contract vs. state forces work and the relative benefits of each.

**Slide 31**



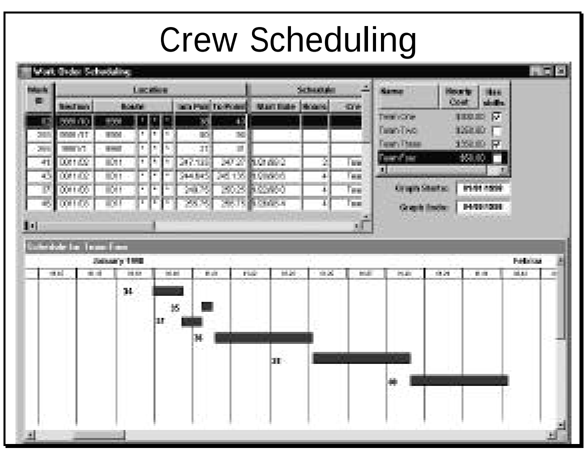

This slide outlines in graphic form how a good MMS system deals with maintenance contracts. The instructor should familiarize him/herself with the slide and share the information based on their review of the reference material.

**Slide 32**




The labor module is an important part of maintenance management. The labor module deals with employees, their assignments and details of their work assignments overhead leave or vacations and other details.

**Slide 33**




This slide shows a graphic of crew scheduling as it develops in a good maintenance management system. There are many ways to do this and this is the example from a specific MMS.
The instructor should outline this information based on his/her review of the reference material and cover the details here.

**Slide 34**

## Equipment Module

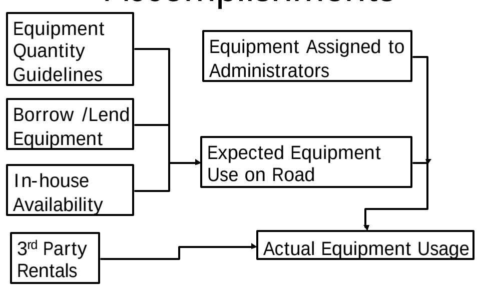
- Fleet and Heavy Equipment
  - Vehicle (equipment) Inventory
  - Repair (in-house or others)
  - Spare parts warehouse
  - Fueling
  - Leasing
  - Fleet Management

11/15/2002 Module 10 34

This slide outlines the four details of a fleet and heavy equipment module from a good MMS. The instructor should cover the material based on his/her experience and review of the reference material.

**Slide 35**

## Equipment Planning & Accomplishments




11/15/2002 Module 10 35

This slide shows a graphic relationship between equipment and its availability and accomplishments within the system. The instructor should review the graphical relationships and summarize the interactions based on his/her experience and review of the reference material.

**Slide 36**

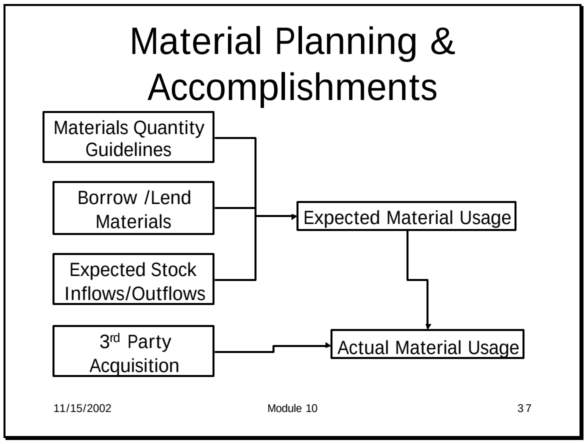
## Materials Module

- Stockpiles at Maintenance facilities and warehouses
- Materials Management
- Use on Projects

11/15/2002 Module 10 36

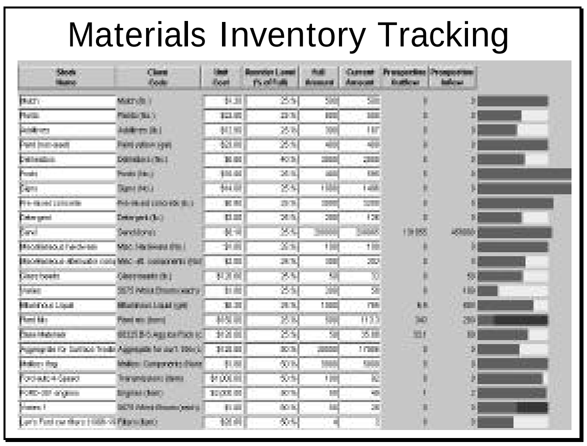
This slide outlines information on stock piles and the use of materials on various projects. The instructor should review them based on his/her experience and review of the project reference document.

**Slide 37**



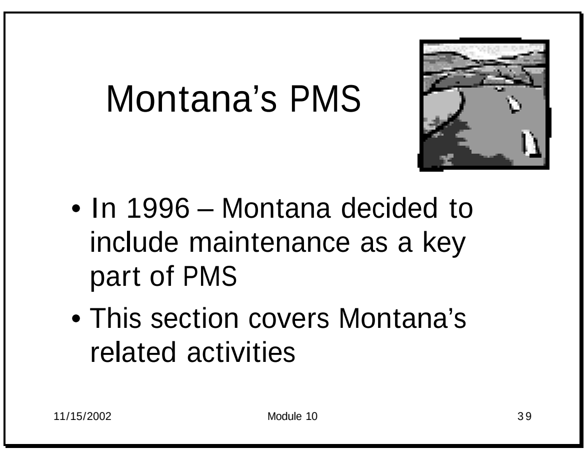

This slide outlines the physical relationship between materials, their planned use and the actual accomplishment or use of materials in the DOT. The instructor should review the graphic relationships and discuss them based on his/her experience and the reading of the reference documents.

**Slide 38**




This slide shows the relationships of the materials and how the inventory can be tracked in various graphical representations in the MMS system for the DOT.

**Slide 39**




In 1996, the Montana DOT decided to include maintenance as a key part of its new PMS. This section covers Montana's related MMS and PMS activities. This slide outlines key points that are going to be covered in this presentation. The instructor should read the bullets from the slide.

**Slide 40**

## Integration of Maintenance in Montana's PMS

- Why look at maintenance
- Understanding maintenance effectiveness
- Effects of maintenance on performance

11/15/2002 Module 10 40

This slide outlines 3 key points that are going to be covered in this presentation. The instructor should read the bullets from the slide.

**Slide 41**

## Why Look at Maintenance

- Many miles in Montana are low volume and rank low in rehabilitation programs
- Consequently maintenance division spends large part of budget on these roads to keep them in serviceable condition

11/15/2002 Module 10 41

This slide points out why Montana thought they ought to look at maintenance as a major part of their PMS. Two major elements are covered and the instructor should review those based on his/her experience and a review of the reference document.

**Slide 42**

## Maintenance History

- At one point, maintenance budget extremely low at $2 million per year providing inadequate maintenance levels
- Maintenance division applied systematic procedures to improve reporting and understanding of maintenance information
- Consequently, additional biennial budget of $13 million per year made available

11/15/2002 Module 10 42

This slide points out in 3 bullets, the 3 major elements of the maintenance history of pavements particularly in Montana. The instructor should cover these points from the slide based on his/her review of the referenced documents.

**Slide 43**

## Keys for Maintenance Program Success

- Adequate recognition of maintenance division
- Systematic analytical processes applied based on high quality information
- High quality of maintenance materials and workmanship
- Room for research and technology innovation in improving overall maintenance process
- Tight integration with PMS, a goal of MDT

11/15/2002 Module 10 43

This slide outlines 5 keys for the success of a maintenance program in Montana DOT. The instructor should read directly from the slide and outline the 5 points based on his/her experience and reading of the referenced documents.

**Slide 44**

## Evaluating Maintenance

- MDT evaluates & records effectiveness of:
  - crack sealing
  - fog sealing
  - chip seals
  - thin overlays
  - non-pavement activities
- Maintenance reports used to update PMS construction records
- Main purpose of evaluation to obtain data for upgrading performance models

11/15/2002 Module 10 44

This slide outlines 3 major elements of maintenance evaluation. The instructor should read from the slide and expand on the items based on his/her reading of the reference documents.

**Slide 45**

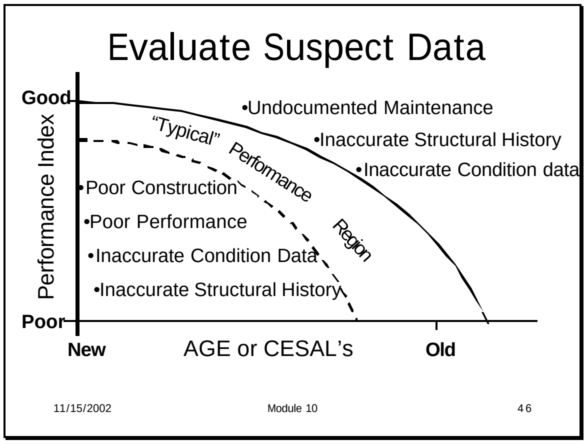
## Maintenance Data Recording

- Details of maintenance work recorded in PMS:
  - location (to the 0.1 mile)
  - application details: equipment, quantities, materials, rates and thickness, etc
  - weather conditions
  - name of contractor or maintenance unit
- New MMS being developed, this will automate data transfer to PMS history file

11/15/2002 Module 10 45

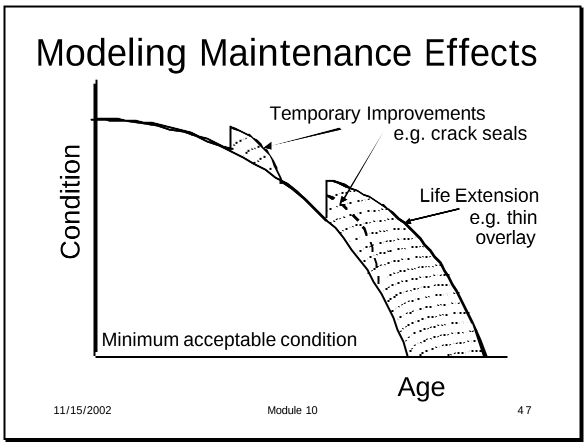
This slide outlines major requirements for recording maintenance data as a part of the MMS in Montana. The instructor should review the slide and cover the points based on his/her review of the reference documents.

**Slide 46**



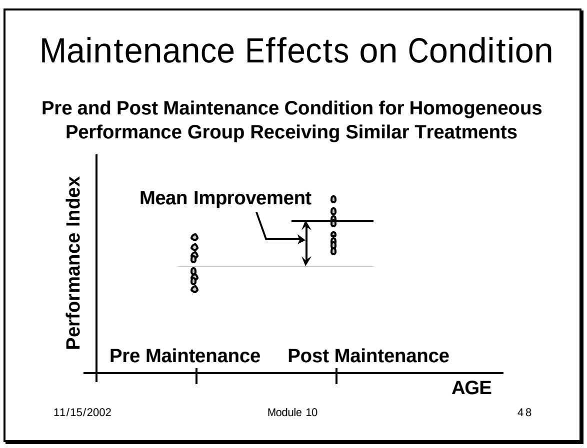

This slide points out the elements that exist in any maintenance database. If data falls out of a typical performance range then the data becomes suspect and the users of the MMS should evaluate that data based on their experience and various check points. The instructor should expand on this concept based on his/her experience.

**Slide 47**




This graphic shows the various effects that maintenance can have on a pavement ranging from temporary improvements to life extensions. The instructor should review this slide for the class based on his/her experience and knowledge of maintenance effects.

**Slide 48**




This slide outlines the effect that good maintenance has on pavement condition or the condition of any element in the maintenance management system. The instructor should review the slide based on his/her experience and review of the reference documents.

**Slide 49**

## Maintenance Effects on Deterioration

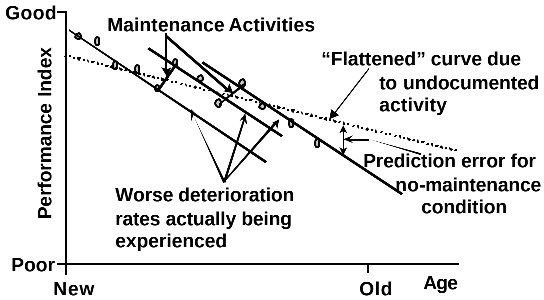
- Undocumented maintenance has "flattening" effect on performance curves
- Records of maintenance activities can be used to delineate performance groups
  - Identification of maintenance policies across varying pavement types
  - Recording of actual maintenance performed

11/15/2002 Module 10 49

This slide outlines 2 major effects that maintenance has on pavement deterioration. The instructor should review the elements on the slide based on his/her experience and reading of the reference documents.

**Slide 50**

## Undocumented Maintenance Effects On Deterioration Curves




11/15/2002 Module 10 50

This slide points out that undocumented maintenance can have a major flattening effect on performance curves. Since the overall plot seems to show that the performance index is deteriorating more slowly than in fact it is. This is a clear example of how important it is that maintenance effects be documented in the maintenance management system.

**Slide 51**

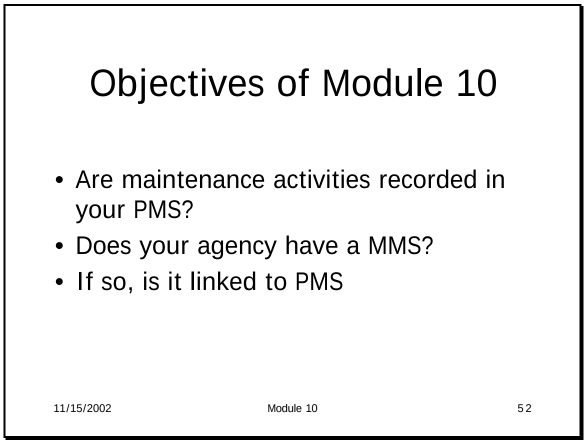
## Conclusions

- Maintenance activities can have major effect on:
  - pavement condition
  - rate of deterioration
  - pavement life
- A properly executed MMS can quantify these effects
- Full benefits occur when MMS and PMS are integrated as in Montana.

11/15/2002 Module 10 51

This slide concludes the section on pavement maintenance/effect on performance. These conclusions derive particularly from the Montana example. The instructor should review those conclusions from the slide but should also summarize the entire section.
After the end of this slide, the instructor should take 5 – 10 minutes for discussion with the class and should stimulate that discussion with appropriate questions and interaction. This is the end of Module 10. At this point, the instructor should point out that a workshop will be held and should prepare the class for that workshop.

**Slide 52**




The instructor should again state the objectives and ask these or any other appropriate question to test the participant’s learning accomplishments.

1. Are maintenance activities recorded in your PMS?
2. Does your agency have a Maintenance Management System?
3. If so, how is MMS linked to PMS?

# Glossary

## GLOSSARY OF TERMS

**AADT**
The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. AADT can also be approximated by adjusting the ADT count for daily (weekday versus weekend) and seasonal (summer versus winter) variations.

**AASHTO**
American Association of State Highway and Transportation Officials

**ADT**
The average 24-hour traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location.

**ADTT**
The average 24-hour truck traffic volume counts collected over a number of days greater than 1 but less than a year, at a given location. ADTT may be expressed as a percentage of ADT.

**Algorithm**
A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps.

**Annual Costs**
Any costs associated with the annual maintenance and repair of the facility.

**Asphalt Emulsion Mix**
A mixture of emulsified asphalt materials and mineral aggregate usually prepared in a conventional hot-mix plant or drum mixer at a temperature of not more than 127 °C (260 °F). It is spread and compacted at the job site at a temperature above 93 °C (200 °F).

**Benefit-Cost Ratio**
The ratio of the dollars of discounted benefits achievable to the given outlay of discounted costs.

**Cape Seal**
A surface treatment that involves the application of a slurry seal to a newly-constructed surface treatment or chip seal. Cape seals are used to provide a dense, waterproof surface with improved skid resistance.

**Capital Costs**
Non-recurring or infrequently recurring costs of long-term assets (including depreciation and property taxes).

**CESAL**

Cumulative Equivalent Standard Axle Loads, e.g. the summation of ESALs over a year (see ESAL).

**Chip Seal**
A surface treatment in which a pavement surface is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low-volume roads.

**Cold In-Place Recycling (CIR)**
A process in which a portion of an existing bituminous pavement is pulverized or milled, the reclaimed material is mixed with new binder and virgin materials, and the resultant blend is placed as a base for a subsequent overlay. Emulsified asphalt is especially suited for cold in-place recycling. Although not necessarily required, a softening agent may be used along with the emulsified asphalt.

**Cold Milling**
A process of removing pavement material from the surface of the pavement either to prepare the surface (by removing rutting and surface irregularities) to receive overlays, to restore pavement cross slopes and profile, or even to re-establish the pavement's surface friction characteristics.

**Combined Performance Indexes**
Combinations of PI's, examples are Structural Index (STI), Surface Distress Index (SDI), Safety Index (SFI), Overall Pavement Index (OPI), Present Serviceability Index (PSI).

**Crack Filling**
A maintenance procedure that involves placement of materials into non-working cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in). Crack filling should be distinguished from crack sealing.

**Crack Sealing**
A maintenance procedure that involves placement of specialized materials, either above or into working cracks, using unique configurations to reduce the intrusion of incompressibles into the crack and to prevent intrusion of water into the underlying pavement layers. Working cracks are defined as those that experience significant horizontal movements, generally greater than about 2 mm (0.1 in).

**CRCP**
Continuously Reinforced (Cement) Concrete Pavement

**Data Mining**
Reviewing existing data, data bases and subsets of data, to determine what information might be available that had previously been overlooked.

**Default Value**
A design value that is based on experience or on studied conclusions and that is used as a substitute value when an actual value is not available.

**Dense-Graded Asphalt Overlay**
An overlay course consisting of a mix of asphalt cement and a well-graded (also called dense-graded) aggregate. A well-graded aggregate is uniformly distributed throughout the full range of sieve sizes.
**Deterministic Model**
A model that expresses the interaction of system elements with complete certainty, that is, as absolute values.

**Diamond Grinding**
A maintenance procedure for concrete pavements that involves the removal of a thin layer of concrete (generally no more than 6.4 mm [0.25 in]) from the surface of the pavement to remove surface irregularities (most commonly joint faulting), to restore a smooth riding surface, and to increase pavement surface friction.

**Diamond Grooving**
The establishment of discrete grooves in the concrete pavement surface using diamond saw blades to provide a drainage channel for water and thereby reduce the potential for hydroplaning and wet weather accidents.

**Discount Rate**
In cost-benefit analysis, an interest rate used to reduce the value of benefits or costs accruing in future years back to their current worth (present value). If the discount rate is 4 percent, $1.04 a year from now is of equal value as $1.00 today.

**Empirical Model –** Prediction based on experience only.

**Emulsified Asphalt**
An emulsion of asphalt cement and water, which contains a small amount of an emulsifying agent. Emulsified asphalt droplets, which are suspended in water, may be either the anionic (negative charge) or cationic (positive charge) type, depending upon the emulsifying agent.

**ESAL**
Equivalent Standard Axle Load, used to transform loads by different vehicles into standard units.

**Equivalent Uniform Annual Cost (EUAC)**
The net present value of all discounted cost and benefits of an alternative as if they were to occur uniformly throughout the analysis period. Net Present Value (NPV) is the discounted monetary value of expected benefits (i.e., benefits minus costs).

**FHWA**
Federal Highway Authority

**Fog Seal**
A light application of slow setting asphalt emulsion diluted with water. It is used to renew old asphalt surfaces and to seal small cracks and surface voids.

**FWD**

Falling Weight Deflectometer, used to assess the structural pavement properties.

**GIS**
Geographic Information System

**Heater Scarification**
A form of Hot In-Place Recycling in which the surface of the old pavement is heated, scarified with a set of scarifying teeth, mixed with a recycling agent, and then leveled and compacted.

**Hot In-Place Recycling (HIR)**
A process which consists of softening the existing asphalt surface with heat, mechanically removing the surface material, mixing the material with a recycling agent, adding (if required) virgin asphalt or aggregate to the material, and then replacing the material back on the pavement.

**Hot Mix Asphalt (HMA)**
High quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate thoroughly compacted into a uniform dense mass.

**Hot Surface Recycling**
See hot in-place recycling.

**Inflation rate**
The rate of increase in the general price levels, caused usually by an increase in the volume of money and credit relative to available goods. The inflation rate is also reflective of the rate of decline in the general purchasing power of a currency.

**Initial Costs**
All costs associated with the initial design and construction of a facility, placement of a treatment, or any other activity with a cost component.

**International Roughness Index (IRI)**
A ratio of the accumulated suspension motion to the distance traveled obtained from a mathematical model of a standard quarter car transversing a measured profile at a speed of 80 km/h (50 mph). Expressed in units of meters per kilometer (inches per mile), the IRI summarizes the longitudinal surface profile in the wheelpath.

**JCP**
Jointed (Cement) Concrete Pavement.

**Joint Resealing**
The resealing of transverse joints in concrete pavements to minimize the infiltration of surface water into the underlying pavement structure and to prevent the intrusion of incompressibles into the joint.

**Joint Sealant Reservoir**
The channel sawed or formed at a joint that accommodates the joint sealant.

**Level of Service**
A qualitative rating of the effectiveness of a highway or highway facility in serving traffic (users), in terms of operating conditions (volume, speed, comfort, safety).

**Load Transfer Restoration (LTR)**
The placement of load transfer devices across joints or cracks in an existing jointed PCC pavement. LTR is used on existing jointed PCC pavements that were constructed without dowel bars at transverse joints.

**Life Cycle Cost Analysis (LCCA)**
An economic assessment of an item, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars.

**Maintenance Management System (MMS)**
Rational procedures that provide optimum maintenance strategies for pavements and related elements like ROW, culverts, guardrails, signs, traffic lights, etc. These procedures are based on predicted maintenance effectiveness and cost for a desired Level Of Service, and the optimal employment of labor, equipment and materials, whilst incorporating feedback regarding the various attributes, criteria and constraints involved.

**Mechanistic Model**
Prediction based on known mechanistic properties of uniform materials, such as Youngs Modulus, strain and stress at break.

**Microsurfacing**
Microsurfacing is a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed and spread on a paved surface.

**Mineral Filler**
A finely divided mineral product, at least 70 percent of which will pass a 0.075 mm (No. 200) sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, portland cement, and certain natural deposits of finely divided mineral matter are also used.

**Model**
A mathematical description of a real-life situation that uses data on past and present conditions to make a projection about the future.
**Nominal Dollars**
Dollars of purchasing power in which actual prices are stated, including inflation or deflation. Hence, nominal dollars are dollars whose purchasing power fluctuates over time.

**NOVACHIP™**
A maintenance treatment for AC pavements, sometimes called an ultrathin friction course: it consists of a layer of hot-mix material placed over a heavy, polymer modified emulsified asphalt tack coat; the total thickness of the application being typically between 10 and 20 mm (0.40 and

0.80 in). It can be used to reduce deterioration caused by weathering, raveling, and oxidation, and can be used to fill ruts and to smooth corrugations and other surface irregularities.

**Open-Graded Friction Course (OGFC)**
An overlay course consisting of a mix of asphalt cement and open-graded (also called uniformly-graded) aggregate. An open-graded aggregate consists of particles of predominantly a single size.

**Overall Pavement Index (OPI)**
A combination of various weighted pavement performance indices (e.g. ride, rutting, cracking, etc).

**Partial-Depth Recycling**
See cold in-place recycling.

**Pavement Distress Index (PDI)**
A combination of several distress ratings.

**Pavement Evaluation**
A technique to measure a range of pavement characteristics such as roughness, rutting, friction and various distresses such as cracking.

**Pavement Management**
A coordinated systematic process for carrying out all activities related to providing pavements.

**Pavement Management Software**
A set of tools to assist decision makers in preserving a pavement network.

**Pavement Management Section**
A location-defined part of the pavement network with a homogeneous cross section, uniform construction history, traffic loading characteristics and history, and uniform drainage and climatic conditions.

**Pavement Management System (PMS)**
A systematic process that collects and analyzes pavement information with rational procedures that provide optimum pavement strategies based on predicted pavement attributes incorporating feedback regarding the various attributes, criteria and constraints involved. PMS is also called PMIS (Pavement Management Information System) or RMS (Roadway Management System).

**Pavement Performance Group**
Grouping of pavement sections for performance models based on Traffic Levels (e.g. AADT), Functional Class (e.g. Interstates, State Highways, etc) and Road Structure Category (RSC)

**Pavement Performance Model**
An empirical or mathematical representation of predicted pavement performance and behavior.

**Pavement Preservation**
The sum of all activities undertaken to provide and maintain serviceable roadways; this includes corrective maintenance and preventive maintenance, as well as minor rehabilitation projects.

**Pavement Preventive Maintenance**
Planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retard future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity).

**Pavement Reconstruction**
Construction of the equivalent of a new pavement structure which usually involves complete removal and replacement of the existing pavement structure including new and/or recycled materials.

**Pavement Rehabilitation**
Work undertaken to extend the service life of an existing pavement. This includes the restoration, placing an overlay, and/or other work required to return an existing roadway to a condition of structural and functional adequacy.

**Pavement Serviceability Index (PSI)**
A subjective rating of the pavement condition made by a group of individuals riding over the pavement.

**Performance Index (PI)**
A combination of weighted performance ratings taken from ride, rutting and other pavement evaluation data.

**Periodic Costs**
Costs associated with rehabilitation activities that must be applied periodically over the life of the facility.

**Poisson's Ratio**
The ratio of the reduced (increased) cross-section under tensile (compressive) stress, to the original cross-section. For an elastic material the ratio is 0.5.

**Present Worth Method**
Economic method that requires conversion of costs and benefits by discounting all present and future costs to a single point in time, usually at or around the time of the first expenditure.

**Probabilistic Model**
Quantification of a future condition using probabilities in an algorithm, where any one of several outputs, each of known probability, can occur for each alternative.

**Quality Assurance (QA)**
The systematic use of performance requirements, design criteria, specifications, production control procedures, and acceptance plans for materials, processes, or products to ensure prescribed properties or characteristics.

**Quality Control (QC)**
The system of collection, analysis, and interpretation of measurements and other data concerning prescribed characteristics of a material, process, or product, for determining the degree of conformance with specified requirements.

**Real Dollars**
Dollars of uniform purchasing power exclusive of general inflation or deflation. Real dollars have a constant purchasing power over time.

**Recycling Agents**
Organic materials with chemical and physical characteristics selected to address any binder deficiencies and to restore aged asphalt material to desired specifications.

**Rejuvenating Agent**
Similar to recycling agents in material composition, these products are added to existing aged or oxidized AC pavements in order to restore flexibility and retard cracking.

**Retrofitted Load Transfer**
See Load Transfer Restoration.

**Road Structure Category (RSC)**
Categorization of pavement structures based on surface material and thickness, underlying pavement structure, and rehabilitation type.

**Rubberized Asphalt Chip Seal**
A variation on conventional chip seals in which the asphalt binder is replaced with a blend of ground tire rubber (or latex rubber) and asphalt cement to enhance the elasticity and adhesion characteristics of the binder. Commonly used in conjunction with an overlay to retard reflection cracking.

**Rubblization**
Technique where existing concrete pavement is hammered into small pieces or chunks of loose material that will act as a granular base.

**Salvage Value**
The remaining worth of the pavement at the end of the analysis period. There are generally two components of salvage value: residual value – the net value from recycling the pavement and serviceable life – the remaining life of the pavement at the end of the analysis period.

**Sand Seal**
An application of asphalt material covered with fine aggregate. It may be used to improve the skid resistance of slippery pavements and to seal against air and water intrusion.

**Seal Coat**
See Chip Seal

**Sandwich Seal**
A surface treatment that consists of application of a large aggregate, followed by a spray of asphalt emulsion that is in turn covered with an application of smaller aggregate. Sandwich seals are used to seal the surface and improve skid resistance.

**Scrub Seal**

Application of a polymer modified asphalt to the pavement surface followed by the broom-scrubbing of the asphalt into cracks and voids, then the application of an even coat of sand or small aggregate, and finally a second brooming of the aggregate and asphalt mixture. This seal is then rolled with a pneumatic tire roller.

**Shape Factor**
The width to depth ratio of a joint sealant reservoir. A proper shape factor is required to allow the sealant to effectively withstand repeated extension and compression as the temperature and moisture in the slab changes. Most commonly available sealants require a shape factor between 1 and 2.

**Slurry Seal**
A mixture of slow-setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to provide skid resistance.

**Stiffness Modulus**
Comparable to Youngs Modulus, but used for non-elastic materials. The Stiffness is defined as the ratio of applied stress to the resulting strain for a certain temperature and time of loading.

**Stockpiled Cold Mix**
An asphalt maintenance mix consisting of aggregate and emulsified asphalt, which once prepared can be stored and readily used for a period up to six months depending on the formulation of the emulsion used and the aggregate characteristics.

**Stone Mastic Asphalt Overlay**
An overlay course consisting of a mix of asphalt cement, stabilizer material, mineral filler, and gap-graded aggregate. A gap-graded aggregate is similar to an open-graded material but is not quite as open.

**Surface Texture**
he characteristics of the concrete pavement surface that contribute to both surface fiction and noise.

**Undersealing**
called sub-sealing, pressure grouting, or slab stabilization: this process consists of the pressure insertion of a flow able material beneath a PCC slab used to fill cavities beneath PCC slabs and occasionally to correct the vertical alignment by raising individual slabs.

**User Costs**
Costs incurred by highway users traveling on the facility and the excess costs incurred by those who cannot use the facility because of either agency or self-imposed detour requirements. User costs typically are comprised of vehicle operating costs (VOC), accident costs, and user delay costs.

**Young’s Modulus or Elastic Modulus**

The ratio of the stress (force per unit of surface area) to the resulting strain (relative increase in length) in a tensile test.